TECHNICAL OPERATIONS RESEARCH

PLANNING DOCUMENT FOR THE RADIATION TEST FACILITY OF THE PROTECTIVE STRUCTURES DEVELOPMENT CENTER

By

John F. Batter
Albert W. Starbird

Report No. TO-B 63-4 Revised
Contract No. DA-18-020-ENG-1929
15 April 1963

Submitted to the

Protective Structures Development Center
Fort Belvoir, Virginia

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INTRODUCTION

This document is designed to provide the backup information required for the successful operation of the Radiation Test Area of the National Protective Structures Development Center. As such it is an assemblage of the knowledge and experience gained from five years of testing both full-scale and model structures in a simulated fallout environment together with general recommendations for test procedures.

The report is divided into eleven distinct sections, each dealing with a single facet of experimentation or providing recommendations as to proposed program and procedure. These eleven sections are:

1. A Suggested Program for the Radiation Facility of the National Protective Structures Development Center
2. Requirements for Radioactive Sources
3. Facility Evaluation
4. Staff Evaluation
5. Equipment and Instruments
6. Calibration and Maintenance of Instruments
7. Source Field Parameters
8. Experimental Design
9. Detailed Operating Procedures
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SECTION 1

A SUGGESTED PROGRAM FOR THE RADIATION FACILITY OF THE NATIONAL PROTECTIVE STRUCTURES DEVELOPMENT CENTER

> Program: Based on the current concept for the Radiation Test Facility as outlined in this report, known gaps in the current state of the art and on the possible requirement in the future, the contractor shall recommend short and long range objectives with appropriate programs for the Radiation Test Facility. A test program to be conducted at the Radiation Test Facility during the remainder of FY 63 and FY 64 shall be developed giving specific objectives, general experimental conditions, procedures, data to be obtained, and the approximate time which should be required for each experiment. Programs shall include establishment of initial operations for checkout.

The purpose of this section is to present a comprehensive experimental program for the radiation test facility that will not only provide training for individuals unfamiliar with "simulated fallout" testing, but will also provide experimental information vital to the civil defense effort. This program is designed to occupy a period of approximately fifteen (15) months beginning in the last quarter of fiscal year 63 and continuing through the entire year of fiscal 64. The suggested program consists of eight separate phases. It should be noted that the suggested program is somewhat different from the preliminary program suggested by the Protective Structures Development Center staff in that there is less repetition of experiments previously done or planned to be done in the near future at other facilities.

The suggested program may basically be considered to be composed of two phases; first, a training phase, and, secondly, an actual experimental phase designed to provide new experimental data.

Fourth Quarter, Fiscal 63 — TRAINING PHASE

I. Calibration of Instruments — Approximately three weeks.

This experiment consists of exposing a horizontal array of dosimeters to radiation from the reference cobalt source and thereby calibrating the dosimeters and the dosimeter reader-chargers. It is suggested that this experiment be performed in the following manner. A horizontal array of 200-mr dosimeters be

set out at an altitude of about eight feet. The dosimeters should be arrayed such that total doses accumulated in four or five minutes range from about 1 mr to 200 mr in steps of about 5 to 10 mr. Exposure should be made in this array with the source at the same height as the detectors for times of five minutes, 10 minutes, 15 minutes, etc., to about 200 minutes. The dose rate at each position may be calculated knowing the reference source strength, the effect of ground scatter[1] and the air density. The results of this series of measurements may then be plotted against reader-charger scale readings to properly calibrate the reader-charger. Similar experimentation should also be performed with the 10-mr instruments.

II. Construction of a Secondary Calibration Range — Approximately one week.

Since simulated fallout experimentation in general requires frequent reference to calibration standards to check erratic dosimeters, a secondary calibration range should be constructed and evaluated. This secondary range consists of a device that allows exact reproduction of source, detector and surrounding scattering geometry no matter when the experiment is performed. Once a device of this sort is constructed (it need only be a piece of plywood permanently mounted near the ground with holes to locate the source and detectors), it may be calibrated for dose rate using the data obtained from the fundamental calibration discussed above. After this secondary range is constructed and evaluated, all dosimeters should be exposed on it to determine the spread in accuracy of the dosimeters.

III. Survey of Perimeter Fence — Approximately one week.

The largest source to be used in the experimental series should be exposed in several locations at the extremities of the experimental field. Dose rate measurements at the outer perimeter fence should be made and recorded.

IV. Calibration of Open Field — Approximately five weeks.

Tubing should be laid down in a pattern similar to that to be used for actual experimentation, except that it must be centered at some point remote from the test structure. For example, a semicircular array may be laid down with its center of symmetry on the opposite side of the 500 x 700 ft test area from the test structure; this will produce a test field with nearly the same characteristics with respect to ground roughness. Measurements of integrated radiation should be made at several

heights and ground locations at, and near, the center of symmetry as well as at one or two points near the middle of the array.

V. Calibration of Test Structure — Approximately three weeks.

The tubing used in Section IV should be picked up and relaid in the same pattern but with its center of symmetry now located in the center of the test structure. Measurements as in Section IV should be repeated with the detector geometry corresponding as closely as possible (with respect to the tubing array) to that used in the open field calibration. Comparison of results will yield the effects of the shelter structure on the radiation field.

Experimental Program

I. Windowless Box Structure Tests.

(1) Comparison with report NDL TR-2 (Use one story single room 12' x 12', floor, 8' ceiling and 8" concrete walls, E=1.0).

(2) Basement structure: roof thickness 4", 8" and/or 12" concrete; L:W ratio of 3:1, E=0.33.

(3) One story structure with basement; roof, floor and wall thickness 4", 8" and/or 12" concrete; L:W ratio of 3:1, E=0.33.

(4) One story compartmentalized structure with basement. (Box within a box).

(5) Two story structure with basement; roof, floor, and wall thickness 4", 8" and/or 12" concrete; L:W ratio of 3:1, E=0.33.

(6) Three story structure with basement; floor, roof, and wall thickness 4", 8" and/or 12" concrete; L:W ratio of 3:1, E=0.33.

II. Barrier Shielding Tests.

Portions may incorporate data and/or be conducted during Windowless Structure Test. Comparison made with charts in manual "Shelter Design and Analysis," Volume No. 1 Fallout Protection, Office of Civil Defense, September 1962. These tests include:

(1) Barrier Shielding Effects (Plane Sources).

B_o. Comparison with Chart 1, Case 1 - Fallout on Horizontal Barrier (X_o).

(2) Barrier Shielding Effects (Plane Sources).

B_w. Comparison with Chart 1, Case 2 - Fallout Adjacent to Vertical Barrier (X_w).

(3) Barrier Shielding Effects (Plane Sources).

B_o'. Comparison with Chart 1, Case 3 - Fallout Adjacent to Horizontal Barrier (X_o').

(4) Wall Barrier Shielding Effects for Various Heights, B_w. Comparison with Chart 2.

(5) Barrier Reduction Factors for Wall-scattered Radiation for Limited Strip of Contamination.

1. Comparison with Chart 9.

2. Data for extending Chart 9.

III. Geometry Shielding Test.

Portions may incorporate data and/or be conducted during Windowless Structure Test. These tests include:

(1) Reduction Factors for Combined Shielding Effects, Roof Contribution, C_o. Comparison with Chart 4; Engineering Manual.

(a) Vary solid angle fraction "w" by adjusting height "Z" and W:L ratio.

(b) Vary number of floors from one to three and mass thickness, 4", 8" and/or 12" concrete between radiation source and detector.

(2) Directional Responses, Ground Contribution, G_d, G_s, and G_a. Comparison with Chart 5; Engineering Manual. (If it is not possible to isolate G_d, G_s and G_a compare total results to that which would be calculated using Chart 5).

(3) Directional Responses for Various Heights, G_d. Comparison with Chart 6; Engineering Manual.

(4) Shape Factor for Wall-scattered Radiation, E. Comparison with Chart 8; Engineering Manual.

(a) L:W ratios of 1:1, 2:1 and 3:2.

(b) Floor, wall, roof thickness 4", 8" and/or 12" concrete.

SECTION 2

REQUIREMENTS FOR RADIOACTIVE SOURCES

Isotope Selection

> Sources: The contractor shall recommend the desirable radiation source size(s), including traveling and point sources, to most economically and efficiently meet his recommended objectives.

Considerable experimentation has been performed during the past five years using cobalt, cesium and iridium as a fallout simulant. The rationale of selection used has been twofold. First, consider the energy spectrum of fallout 1.12 hours, 23.8 hours and 9.82 days after fission (see Figure 1). The spectrum at early times is rather uniformly distributed between about 0.5 to 2 Mev with a peak at about 1.5 Mev. At slightly later times this peak becomes more pronounced and decreases in energy such that at 23.8 hours approximately 75 per cent of the dose from fallout distributed over a plane arises from the absorption of photons of between 0.6 and 1.2 Mev. At still later times, of the order of 10 days, the average photon energy again increases and averages about 1.3 Mev. Thus, the fallout simulant selected should contain predominate photon energies in the range of 0.5 to about 1.5 Mev. Secondly, increased confidence is generated in calculations based upon the fallout energy spectrum if there exists good agreement between similar theory and experiment based upon a known isotope. Thus, the selection of the proper isotope to use for a fallout simulant is based upon both approximate representation of the fallout energy spectrum and the availability of similar theory for both fallout and the isotope in addition to such physical features as availability of the isotope, high specific activity to create effective point sources, half-life sufficiently long to make useful experimentation possible, etc.

Cobalt-60 has been selected as the primary fallout simulant by most investigators because in addition to its desirable features of ready availability, high specific activity and long half-life, its photon energies represent the higher energy portion of fallout spectrum at early times and a large volume of theoretical techniques have been developed about this isotope.[2] Additionally, since the penetration

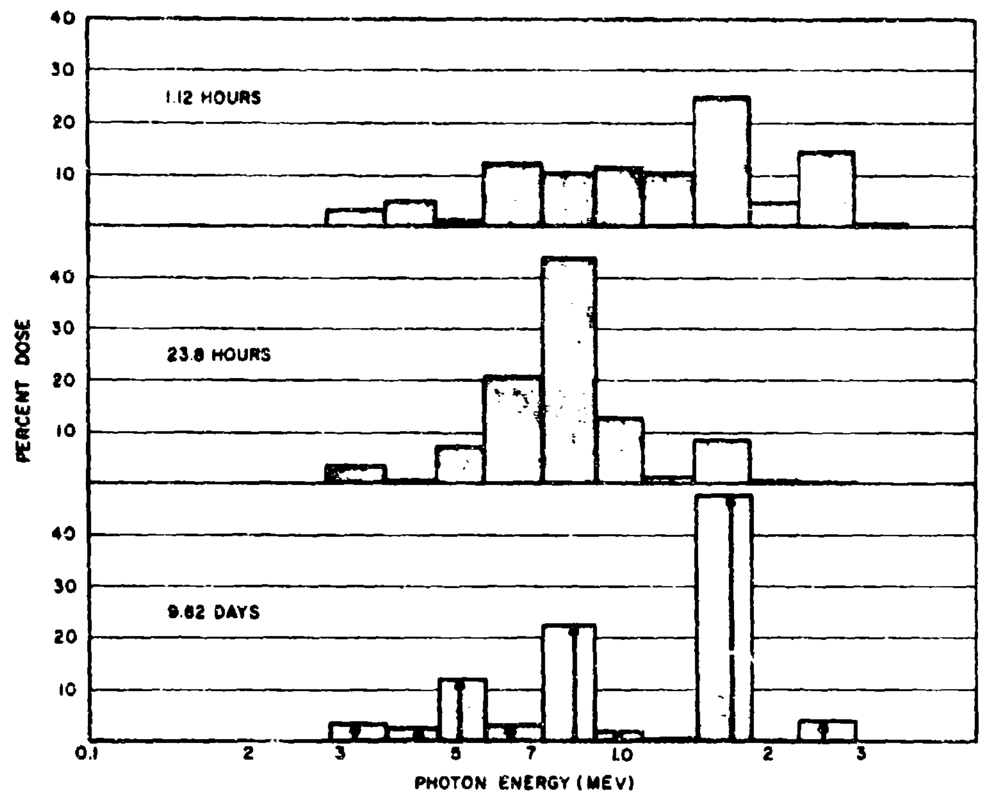


Figure 1. Distribution of Dose 3 Ft Above Infinite Plane Contaminated With Fallout of Various Ages (Volatile Products Removed)

of gamma rays through matter is most typified by its higher energy components, an isotope emitting photons of energy equivalent to the upper region of fallout energy spectrum should penetrate in a quite similar manner. Figure 2 presents the computed attenuation curves for cobalt-60 radiation and 1.12-hour fallout radiation for the three geometric cases of interest: Case I, contamination on a barrier; Case II, contamination next to a vertical barrier; and, Case III, contamination next to a horizontal barrier.

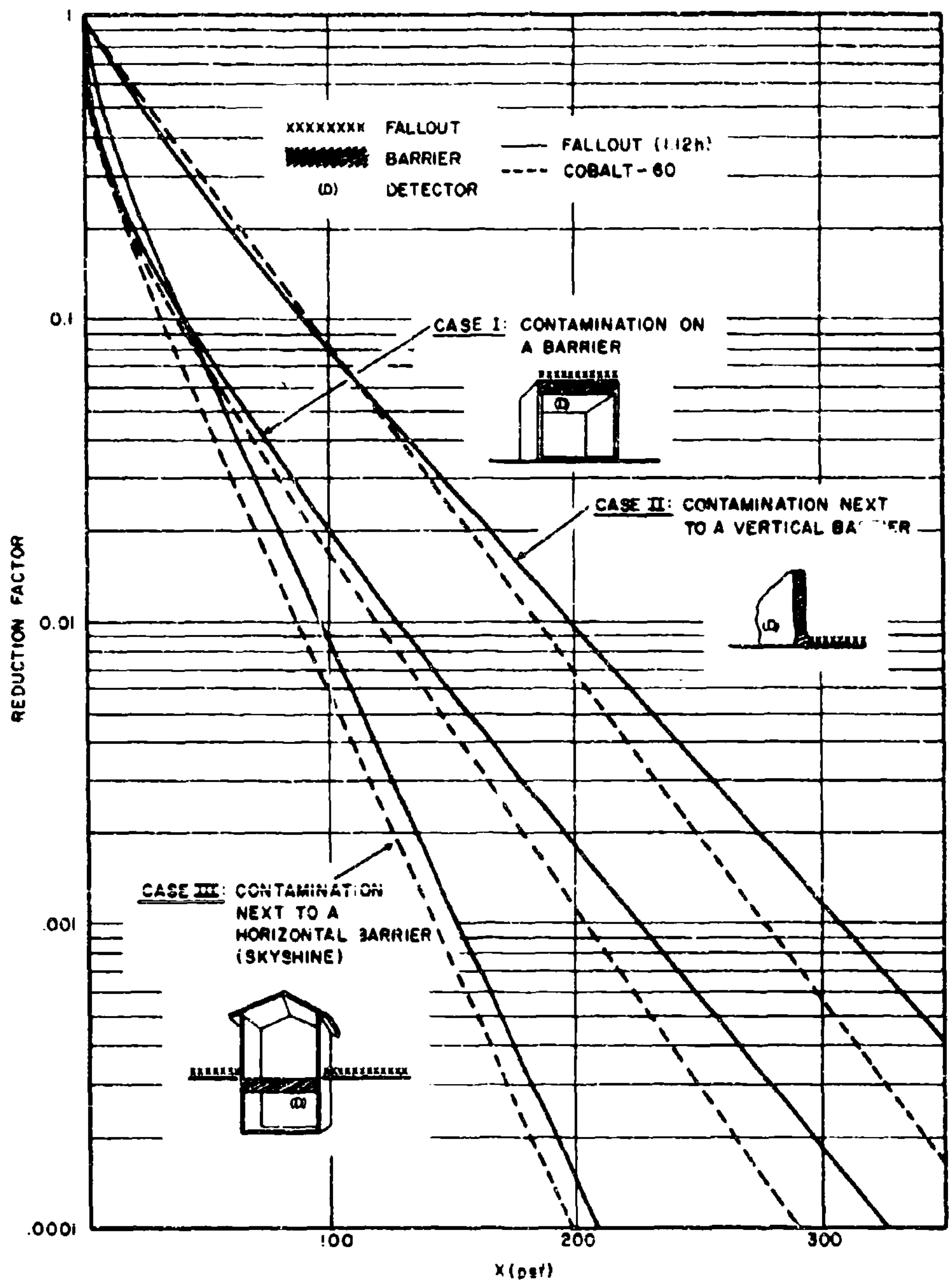


Figure 2. Penetration of 1.12-Hour Fallout and Cobalt-60 Radiation Into Concrete (from Spencer[3])

Iridium-192 and cesium-137 have also been used by many investigators as a fallout simulant. Since the energy of the photons (approximately 0.4 Mev and 0.66 Mev respectively) represent the lower portion of the fallout energy spectrum, there is some justification for using these isotopes at the Protective Structures Development Center. Each of these isotopes exhibits a particular disadvantage, however; low specific activity of cesium-137 prohibits fabrication of high-strength sources of small physical dimensions, thereby significantly increasing container costs; cesium's extreme solubility in water also makes leaks dangerous, while iridium's short half-life (75 days) requires rather frequent replacement. Thus, although there is a sufficient body of theory built about these isotopes and they adequately represent a portion of the fallout energy spectrum, they must be considered as isotopes of secondary importance from a practical standpoint.

Source Sizing Requirements

The source strengths for use at the Protective Structures Development Center should in general be as great as possible to permit accurate measurements to be made in structures having protection factors of the order of 1000.

The upper limit of source strengths is set by the fact that the dose rate at the exclusion fence must not exceed 2 mr/hr with the source located anywhere in the test array. In addition, the physical dimensions of the source must be such that it can be accommodated in tubing of minimum diameter. This is necessary because the effective ground roughness introduced by the tubing through which the source must travel must be kept to a minimum.

The maximum allowable source strength is based upon the Atomic Energy Commission's requirements for permissible levels of radiation in unrestricted areas. Paragraph 20.105 of the Nov. 17, 1960 edition of the Commission's Rules and Regulations states "no licensee shall...create in an unrestricted area... (1) radiation levels...in excess of two millirems in any one hour, or (2) radiation levels...in excess of 100 millirems in any seven consecutive days. Thus, since the dose rate, D, at a distance, d, from a source of strength, S, may be written as the product of a simple exponential and a buildup factor, the

source strength that will produce the maximum value of 2 mr/hr at the exclusion fence may be written as:

$$S = \frac{Dd^2 e^{d/\lambda}}{qB(d/\lambda)}$$

where S = Source strength in curies

D = Maximum allowable dose rate at exclusion fence = .002 R/hr

d = Distance in feet

λ = Mean free path (ft)

q = Dose rate per curie at one foot from the source

$B(d/\lambda)$ = Dose buildup factor.

The constants required to evaluate the relationship are:

	Co^{60}	Cs^{137}	Ir^{192}
λ	445	330	280
q	14.0	4.2	5.9 R/hr curie at 1 (ft)
$B(d/\lambda)^{*3,4}$	$1.10+\frac{d}{840}$	$1.05+\frac{d}{480}$	$1+\frac{d}{280}$ (estimate)

*Source located on the ground, detector at three-ft height (see Figure 3).

If the minor attenuation introduced by ground roughness is neglected, the maximum allowable source strength for an exclusion distance of 1000 feet (that of the Protective Structures Development Center's Radiation Test Area) may then be calculated as:

	Co^{60}	Cs^{137}	Ir^{192}
B(1000 ft)	2.25	3.1	4.5
S	600	3200	2600 curies

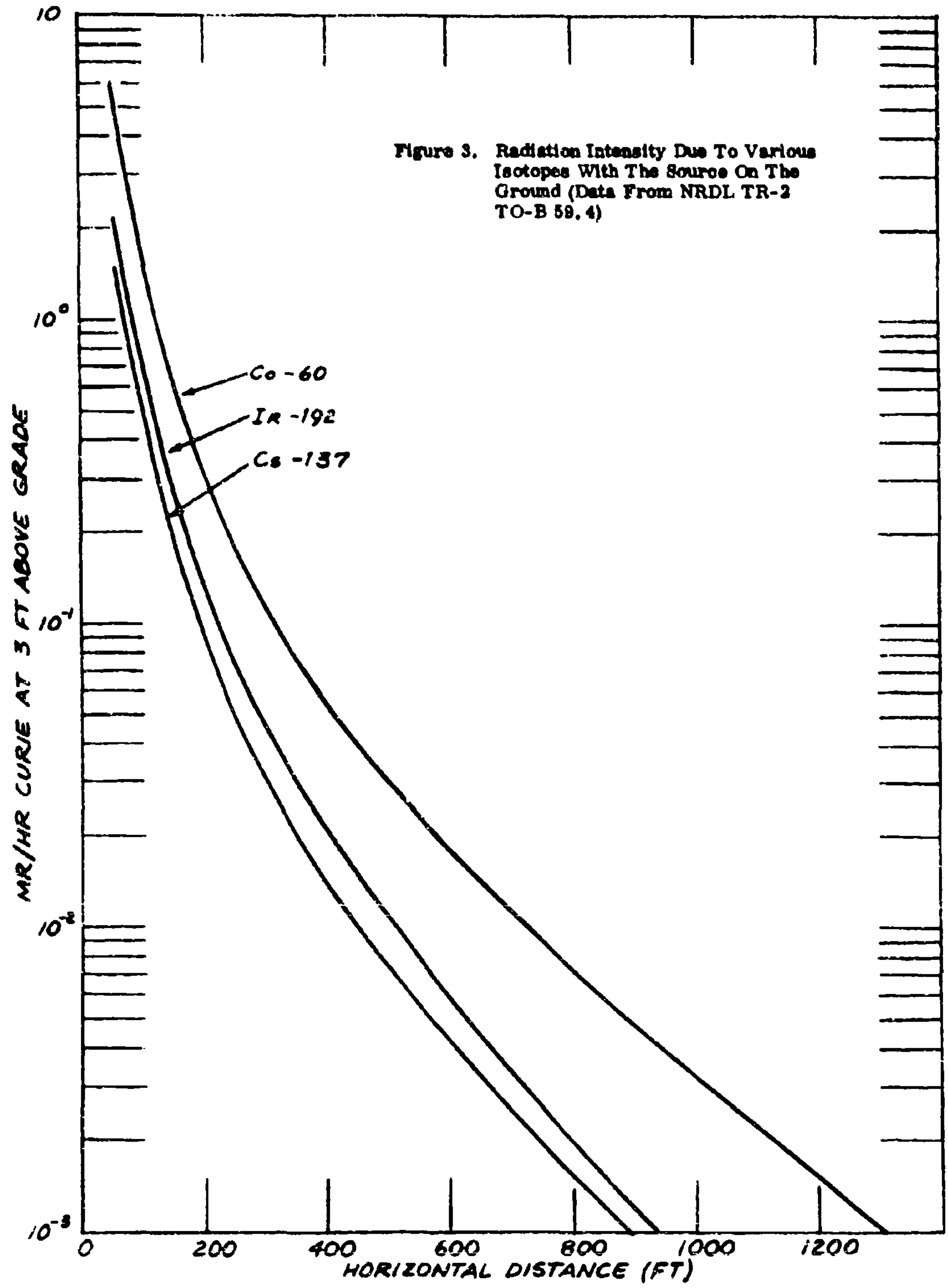


Figure 3. Radiation Intensity Due To Various Isotopes With The Source On The Ground (Data From NRDL TR-2 TO-B 59, 4)

The need for adequate radiation intensity to meet expected experimental requirements sets a lower limit on the allowable source strength. The dose rates 3 ft above infinite fields of cobalt, iridium, and cesium at densities of 1 curie/ft^2 are approximately 500, 200, and 140 r/hr respectively. A semicircular annulus extending from 16.6 ft-radius (equivalent to the area of the basement structure) to 200-ft radius would create a field at its point of symmetry of only about 25 per cent of infinite field values, almost independent of the isotope used. Similarly, a quarter-circular annulus extending from 16.6 to 500-ft radius would produce only about 16 per cent of infinite field values. If each field were divided into four annular areas each capable of producing similar dose rates in the structure, each experimental area would be capable of contributing about 6 per cent of the infinite field dose rates in the case of the semicircular field and 4 per cent of infinite field dose rate in the case of the quarter-circular field. The approximate radii and area of these annuli are illustrated in Table I.

TABLE I

EXPERIMENTAL AREAS

Area	Semicircular Geometry				Quartercircular Geometry			
	Inner Radius (ft)	Outer Radius (ft)	Area (ft^2)	Approximate Value of Infinite Field (%)	Inner Radius (ft)	Outer Radius (ft)	Area (ft^2)	Approximate Value of Infinite Field (%)
1	16.7	30	983	6	16.7	35	750	4
2	30	55	3,340	6	35	75	3,460	4
3	55	100	11,000	6	75	170	18,300	4
4	100	200	46,800	6	170	500	174,000	4

Thus, since the simulated source density is equal to the source size multiplied by the time of exposure divided by the area over which the source travels, the total

accumulated dose at the center of the structure about which the field is simulated is:

$$D = \frac{FI_oTS}{AP_f}$$

where
- D = Total accumulated dose in the structure
- I_o = The dose rate 1 m above an infinite field of density 1 curie/ft^2
- S = Source strength in curies
- T = Exposure time in hours
- F = Fraction of infinite field represented by the experimental area
- A = Area of simulated field (ft^2)
- P_f = The protection factor afforded by the structure from ground based sources of radiation.

This relationship permits determination of the minimum and maximum source strengths required. Thus the minimum source strength required to obtain 1 mr (about ten times the natural background radiation) in the maximum practical exposure time of 10 hrs in a structure of P_f of 1000 when the source is in the outermost annulus would be, in curies:

	Co^{60}	Cs^{137}	Ir^{192}
Semi-Circular Annuli	156	550	390
Quarter-Circular Annuli	870	3100	2200

This then would correspond to the minimum source size desirable to obtain reasonable readings from the outermost annulus. The maximum source size is set by the capacity of the detectors to record the unshielded dose in the shortest practical exposure time from the innermost annuli. Thus the source strength in curies required over the innermost annulus to obtain a dose of 200 mr in an exposure time of 1/10 hrs at the center of a structure of unity P_f would be:

	Co^{60}	Cs^{137}	Ir^{192}
Semi-Circular Annuli	66	230	160
Quarter-Circular Annuli	75	270	190

This clearly illustrates that two sources of each isotope selected are required to cover the range of expected experimental conditions: first, a large source for use in the farthest experimental areas with structures exhibiting high protection factors and, second, a source approximately an order of magnitude smaller for use with lightly-protective structures with close-in areas of simulated contamination. In summary, the foregoing criteria place the following limits on required source sizes:

	Co^{60}	Cs^{137}	Ir^{192}
Maximum source size 2 mr/hr limitation at outer fence	600	3200	2600
Minimum source size required to produce 1 mr with 10 hours exposure in structure of P_f=1000 semi-circular annulus	156	550	390
Minimum source size required to produce 1 mr with 10 hours exposure in structure of P_f=1000 quarter-circular annulus	870	3100	2200
Maximum source size required to produce 200 mr with 1/10 hour exposure in a structure of P_f=1 semi-circular annulus	66	230	160
Maximum source size required to produce 200 mr with 1/10 hour exposure in a structure of P_f=1 quarter-circular annulus	75	270	190

From inspection of this table it may be noted that the maximum source strength is limited by the exclusion distance only in the case of cobalt. This limitation, owever, is not critical as it causes a reduction of only 30 per cent in the desired rce strength. This in turn requires the acceptance of 0.7 mr as the maximum r ing that would be obtained in an exposure of ten hours with a structure of $_f$ = 1000 when the source is in the outer annulus of the quartercircular field. This value is sufficiently above background level that good readings may be obtained.

In the case of cesium, however, while the strength of the large source is below the maximum allowable by exclusion area limitations, it should be noted that its low volumetric specific activity (65 curies/cm^3) prevents fabrication of such a source to be handled by presently developed equipment. For example, a cesium-137 source of 3100 curies designed to be propelled through 1/2-inch inside diameter tubing would have to be about 42 inches long, and would thus require a much longer container to keep it shielded.

It is thus concluded that the source requirements of the radiation test facility of the Protective Structures Development Center are best met with the following source sizes:

Primary Sources — 600 and 60 curies Cobalt-60

Secondary Sources — 230 curies Cesium-137, 160 curies Iridium-192, and 2200 curies Iridium-192.

In addition, since experimental work of this nature often requires recourse to fundamental standards, calibration sources are required. These sources, since they must be frequently used, should be exposable by remote operation. Previous experience has shown that source sizes of the value of 1/2 curie of cobalt-60, 5 curies of cobalt-60, 1 curie of cesium-137 and 2 curies of iridium-192 are most convenient for calibration use. These sources should be capable of being exposed by remote operation.

SECTION 3

FACILITY EVALUATION

> Facility Evaluation: The Radiation Test Facility at the Protective Structures Development Center as currently contemplated shall be evaluated by the contractor to insure that safety considerations laid down by the AEC will be met including such items as fencing, gates and warning devices. Calculation shall be made to insure that both operating and outside personnel will be adequately shielded under all reasonable conditions. If the layout appears inadequate, recommendations for corrections shall be made.

General Description

The Radiation Test Facility at the Protective Structures Development Center is located within a 170-acre, fenced-in section of Fort Belvoir, Virginia. This site is essentially a 2700' by 2500' rectangular area sloping from a height of 90-feet elevation to 30 feet. A limited-access road passes lengthwise across the site entering at an elevation of 70 feet. A 500' by 700' stabilized test pad is located at the center of the site with a minimum distance of 1000 feet from the edge of the pad to the fenced edge of the site (see Figure 4).

Experimental structures are to be erected over a 24 x 36-foot foundation located along one of the test pad edges 200 feet from one corner of the stabilized area. A steel framework above the foundation facilitates mockup of concrete structures from 4-inch-thick building blocks. This framework design is based on six 12 x 12-foot modules for each of three above-ground floor levels. The foundation is located such that a 500-ft radius quarter-circular fallout contamination area can be simulated. A 100 x 100-foot hardened area around the foundation serves as a work area for erection of experimental structures. Two 8 x 8-foot square lockable storage buildings are located approximately 100 feet from the foundation for the storage of tools and radioactive sources. A paved strip along the foundation side of the stabilized pad permits wheeling of source containers from the storage building into position for connection to source field tubing.

A control bunker approximately 200 feet from the test pad protects operating personnel during source exposure. An observation tower associated with the bunker permits visual survey of the test area.

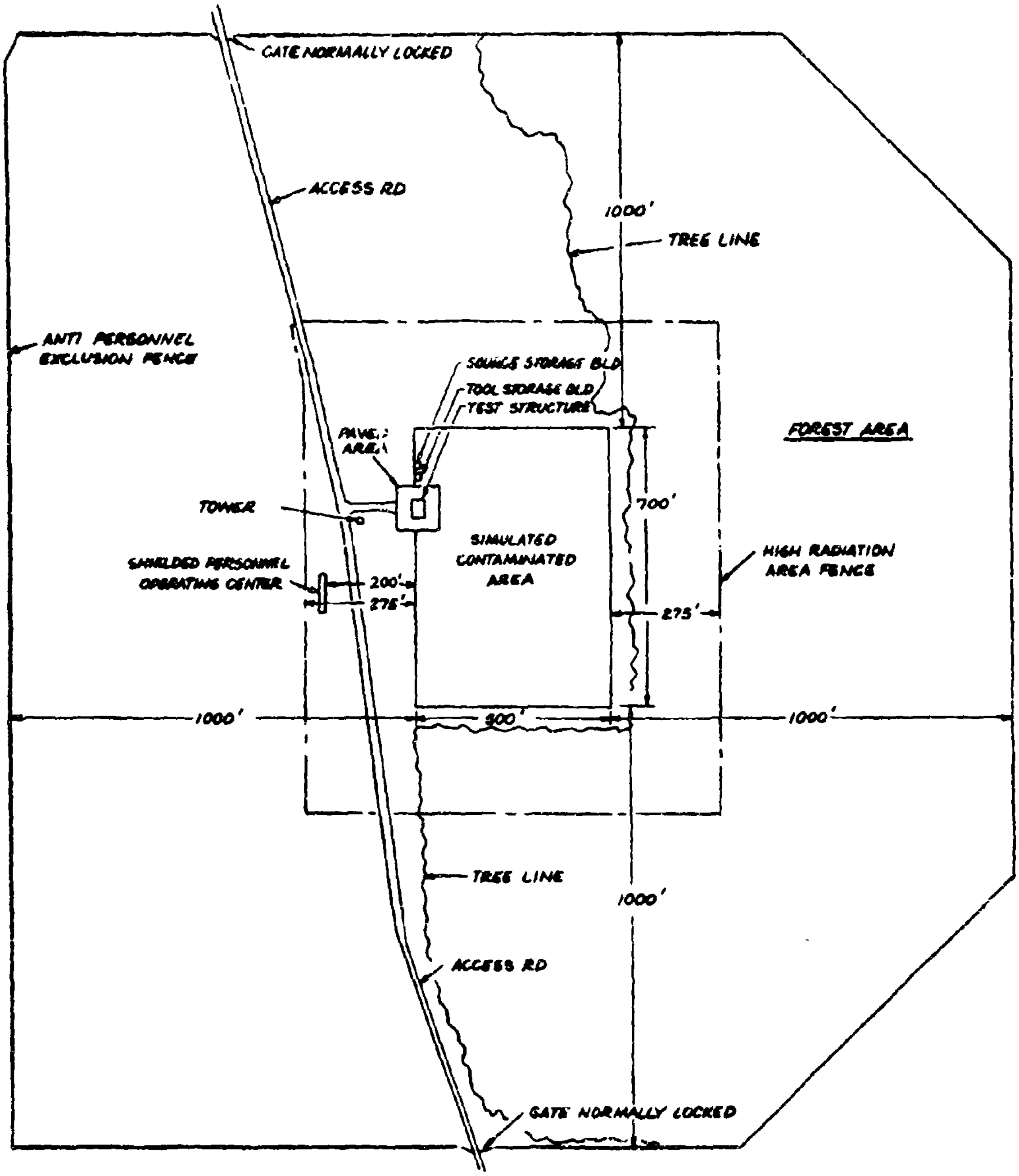


Figure 4. Schematic Drawing of a Radiation Facility at the National Protective Structures Development Center

Exclusion Fence

The outer exclusion fence consists of six-foot-high chain-link fencing topped with a barbed wire overhang. A paved road to be used both as access to the radiation facility and limited use for general vehicle traffic across the area when the facility is not in operation (all radioactive sources safely stored and locked) requires a gate to be placed on each of the two sides of this fence where the road passes through. The radiation conditions outside this fence must be such as to meet AEC requirements for unrestricted areas. A person continuously present at or outside this fence must not receive more than two millirems in any one hour, or 100 millirems in any seven consecutive days. Also, no person in the unrestricted area should receive more than 0.5 rem to the whole body in any period of one calendar year. In this case the controlling factor for the unrestricted area adjacent to this site is the 2-mr limit for any one hour. Source exposure time for the planned experiments will not approach the 50 hours per week required to exceed the 100-mr restriction, even assuming the source to be at one point on the edge of the stabilized area for this length of time. Both the main entrance as well as the gate on the opposite side of the facility will have locks and will be alarmed for positive audio monitoring by personnel within the exclusion area. This alarm will be a loud horn, bell or buzzer device that can be heard at both the control bunker and test pad areas. When the facility is not in operation these alarms will be deactivated to permit vehicle passage across the facility.

Warning Lights

Flashing red lights are required at each of the two gates (two per gate) to indicate that a radiation source exposure is being made. These lights are manually turned on by the operating crew prior to unlocking any radiation source container and are not turned off until all sources are properly locked in their containers. It might be convenient if this alarm system also operates a sign at the wye in the access road to the main gate that will indicate whether the road across the facility is open and if a test is in progress. This will prevent people for driving up a dead end road. There should be a telephone at the main gate for contacting test personnel inside. A guard post just inside the main gate of the facility is provided for additional flexibility in controlling access. "Caution Radiation" signs meeting AEC design require-

ments should be placed on the gates and at least every 100 feet along the entire length of the fence and closer where necessary for the warning signs to be conspicuous. Instructions at the gate will state that film badges and dosimeters are required for access to the facility area and that badges and dosimeters may be obtained at a given building.

Inner Fence

To meet AEC safety requirements for a permanent radiation facility an inner exclusion fence denoting the high radiation area (the area where an individual might receive 100 millirems or more in one hour) must be added. This fence must have an alarm system extending around its entirety such that an individual climbing the fence or opening a gate will cause an audible alarm signal that will be heard by the test personnel. It is recommended that the fence be a 3-wire fence about 3 ft high with the top wire acting as an alarm wire. A simple alarm system that may be used consists of an alarm wire passing through holes in metal brackets on the fence post such that deflection of the wire will cause it to short against the bracket and close the alarm circuit. There should be alarmed gates at both points where the facility road passes through the fence. The same flashing red light warning (two per gate) system as for the outer gates also applies for the inner gate. "Caution High Radiation" signs of proper design should be mounted on the gates and conspicuously along the outer side of the fence with a maximum spacing of 100 feet between signs. The two road gates should be locked during source exposure. This inner fence will be 275 ft from the stabilized test pad giving a maximum dose rate of 100 mr/hr at the fence with any of the listed sources on the edge of the stabilized area.

The number of access gates into the high radiation area should be kept to a minimum. A walk-in gate is required for connecting the test pad with the control bunker outside the "high radiation" area. Ideally, access to this gate should be through the control bunker only in which case this gate would not have to be locked during a source exposure as long as the operating personnel are in the bunker. This gate should still be alarmed, however. If for practical reasons gate access has to be made independent of the control bunker, then this gate must also be locked during source exposures when not directly monitored by operating personnel.

A third vehicle gate is necessary for convenient access between the test pad and the bunker area while structures are being erected or modified. This gate must also be alarmed and locked during radiation tests.

Personnel Shield

A combined control and personnel protection bunker should be located as close to the test area as practical (approximately 200 feet). Radiation levels inside the bunker should approach background values and must not exceed maximum values of 2 mr/hr. To achieve this it is suggested that a quonset-type structure be erected and covered with earth. If the minimum earth cover is of two feet thickness at the top with a maximum side slope of two in three the maximum dose rate expected in the shelter will be 0.5 mr/hr with the 600-curie source located a distance of 100 feet away. The pump console should be positioned in, and the remote controls for the fence warning lights should be operable from, the bunker. The lead lengths required for this position of the pump console would be about the same as required if the pumps were placed in one of the tool sheds on the pad. From the tool sheds a lead length of approximately 600 feet is required to reach to the outer tubing loop, while with the pumps located in the bunker the length of tubing leads would also be about 600 feet. With the pumps mounted in the bunker emergency operations such as reversing pump leads could be performed in a relatively negligible radiation field. Checks of pump operation and system pressures could be safely made. A sump pump may be required for the bunker if water level problems are encountered. If it contains sufficient room, this bunker may be additionally used as laboratory and office space for the personnel operating the facility. A portion of the structure could be used as a secondary calibration range with the calibration sources if sufficient loose, solid concrete blocks were provided to stock a shielding wall between it and the office area.

A tower should be erected in conjunction with the bunker to permit the operating personnel to survey the whole "high radiation" area prior to exposing a source. The tower can also be used to locate the position of a source stuck in a tubing circuit with the aid of a spotting scope. The field of view from the tower should include all of the high radiation area except that blocked by the test structure. The blocked region area will have to be checked visually by test personnel as they leave

the high radiation area prior to exposing a gamma source. The field of view requirement may necessitate removal or limbing of some trees within the high radiation area and of trees located between the tower and the inner fence.

"Caution Radioactive Material" signs shall be conspicuously posted inside and outside the source container storage areas (tool sheds). Form AEC-3 "Notice to Employees" should be conspicuously posted at several locations within the facility such as the guard house, control bunker and tool houses. Portable floodlight units should be provided capable of lighting any portion of the 500 x 700-ft test pad in the event of an emergency after dark. This could occur if a malfunction occurs near the end of a normal winter work day allowing little time for emergency procedures to be initiated before darkness sets in. The light level should be on the order of 2-5 foot-candles. In addition, lighting must be provided for the interior of the test structure.

SECTION 4

STAFF EVALUATION

Staff Evaluation: The proposed staffing (numbers and skills) of the RSDC as shown on the current organization chart shall be evaluated and recommendations given for any changes required to meet the recommended objectives.

RADIATION SHIELDING DEVELOPMENT SECTION
(Organization)

The Radiation Shielding Development Section is responsible for operation of the Experimental Shielding Facility. It plans and carries out appropriate tests on structures, components or systems. Further, it must analyze and evaluate the data from the test program to assure the results are meaningful for the over-all shelter program.

To accomplish this mission it is recommended that the following organizational pattern be established. The basis for this recommendation is the experience of other groups, governmental and industrial, in planning and carrying out similar test programs. Two groups are established under the Section Chief. An experimental field team is required to perform the actual experiments. This is headed by a Field Engineer and composed of the Engineer and two technicians as assistants. These technicians have separate skills best described as mechanical and electronic. Thus adequate capability is assumed to handle procedures and problems involved in field operation of pumps, motors, valves, switches, etc., and erection of structural components, as well as the special nuclear radiation detection equipment (counters, dosimeters and readers, ion chambers, etc.). It has been found by experience that a combination of these skills in a three-man team is a highly efficient operating group for field experimentation such as is conducted at the Facility. Two laborers suffice to provide assistance in handling and erecting structural materials.

To provide the analysis and evaluation of the data obtained from the tests a separate group is established in the Section. The physicist heading this analysis group has the responsibility for the work, but to provide the necessary tie-in with

the experiments and with the over-all program and planning both the Field Engineer and the Chief of the Section contribute to the work of the group. One well-qualified analyst assisted as described should be able to handle the output of the field team. It is also suggested that this person serve as Health Physics Officer for the Facility.

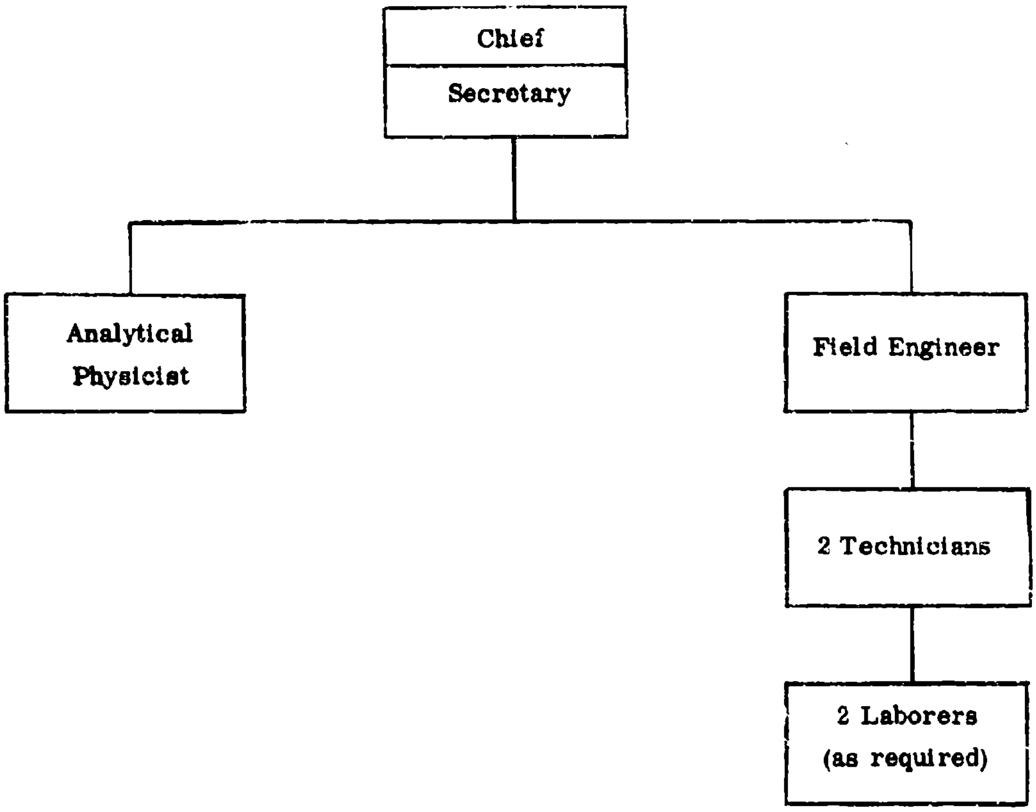


Figure 5. Staffing Diagram

RADIATION SHIELDING DEVELOPMENT SECTION
(Staffing Pattern)

I. Chief

Functions and Duties

This position provides the guidance necessary to accomplish the objective of the Radiation Shielding Development Section. The incumbent is responsible for planning, implementing and directing the activities of the Section. Supervision is minimal and limited primarily to non-technical aspects of the shielding program of the Section. Thus, mature technical judgment based on experience in management of scientific programs and in research, and field and laboratory experiments in radiation shielding is necessary.

The duties of this position are primarily those related to the design, development and execution of tests to provide technical and scientific data on radiation shielding afforded by structures, components, or systems required to further an integrated shelter program for the country. The planning and direction of such a test program is estimated to require approximately one-half of the incumbent's time. To assure that the projects undertaken by the Section are producing adequate results, approximately one-quarter of the incumbent's time will be required for analysis and evaluation of the results of the tests performed. To obtain optimum benefit from the operation of the Experimental Shielding Facility it is necessary to insure that the results are evaluated and presented in a manner to be of maximum benefit to subsequent users. Errors in judgment or improper decisions on the part of the incumbent could seriously jeopardize the adequacy of the results of the Section's program.

Since the Facility will serve as a focal point for experimental structure shielding work, it is expected that personnel both scientific and other from both government and industry will visit the Facility. The incumbent provides the liaison with such groups to describe the Center's shielding programs and objectives as required. He must thus have the ability to present technical concepts to groups of widely diversified backgrounds.

The technical direction of the test program of the Section requires the incumbent be an individual who combines the qualities of a research scientist and a technical administrator. He must be capable of applying mature judgment based on experience to the technical problems encountered in the test programs. The incumbent shall have sufficient experience in handling radioactive sources comparable to those to be used at the Center to qualify him for the necessary AEC licenses and shall also be qualified to serve as Deputy Health Physicist in the absence of the designated Health Physicist.

Evaluation of Position

In view of the importance of this position to the successful operation of the Facility, it is necessary that the incumbent be a highly qualified scientific person. The position should be rated at a minimum as a GS-14 and it is highly probable that it would have to be higher to provide a salary range commensurate with the required qualifications. Training and experience in either nuclear engineering or physics would be required for qualification.

II. Physicist

Functions and Duties

This position provides to the Chief, Radiation Shielding Development Section the capability for scientific analyses and evaluation of the experimental data obtained in the projects undertaken by the Section. It further provides the health physics surveillance necessary to insure safe operation of the Shielding Facility. Under the direction of the Chief, incumbent is responsible for analysis and evaluation of the data resulting from the experimental program. Incumbent's advice is sought to insure that the experimental program will provide data adequate in regards to both its nature and accuracy. Familiarity with methods of analysis used in radiation shielding and results of experimental and theoretical calculations performed by other investigators is necessary. Approximately three quarters of the incumbent's time is devoted to the analysis and evaluation of the experimental test program.

The incumbent is also responsible for: obtaining and maintaining records of personnel exposure; providing save operating instructions for performance of the tests to be conducted; insuring that proper safety precautions are observed during actual operation, e.g., checking the safety controls for the test area and its access points, checking radiation levels at the operating stations of project personnel; assuring safe storage conditions for radioactive sources; performing necessary source checking including leak tests. Incumbent should possess sufficient experience with sources comparable to those used at the Facility to qualify him for necessary licenses. In the absence of the Chief, incumbent will assume the duty of escorting visitors at the Facility.

Evaluation of Position

The requirement for the necessary background and experience in shielding analysis and health physics indicates that the position should be at least a GS-13 and would require a physicist or nuclear engineer with a strong background in field test programs.

III. Engineer

Functions and Duties

This position provides to the Chief, Radiation Shielding Development Section capability for direction of the field operations necessary to implement the projects undertaken. Under the guidance of the Chief and with the advice of the Physicist in regard to type of data necessary and operational safety requirements, incumbent is responsible for detailed planning and performance of the specific tests conducted at the Experimental Shielding Facility. Erection of structures and/or their components, placement and reading of instruments and manipulation of radioactive sources are performed under direct guidance of the incumbent. His experience with sources such as employed at the facility should be sufficient to qualify him for necessary licenses. Approximately three-quarters of incumbent's time is devoted to field experimentation. Calibration (both of sources and instrumentation), and maintenance or modification of all experimental equipment used is performed under his supervision. Incumbent is also responsible for initial processing and analysis of data obtained in tests.

Evaluation of Position

The requirement for broad experience with mechanical, electrical, special electronic nuclear radiation detection equipment and radioactive sources indicates that this position should be rated at a minimum as a GS-13. Qualifications would require a mechanical engineer, nuclear engineer, or equivalent, with radiation experience.

IV. Technician (Equipment Operator)

Functions and Duties

This position provides operating capability to the Experimental Shielding Facility with emphasis on operation and maintenance of mechanical and electrical equipment. Incumbent is under direct supervision of the Engineer directing field tests but is himself responsible for proper performance of equipment in his field of competence. Special design or modification of appropriate equipment required to accomplish specific objectives of a test is the responsibility of the incumbent. He will also perform necessary calibration and operating checks.

Evaluation of Position

Since the success of the experimental operations will depend on proper operation of equipment, and on knowledge of capability, limitations, reliability, and possible modification of equipment to meet necessary requirements, the position requires that the incumbent possess a background of practical experience. A rating of GS-9 would be minimal. Based on industrial experience with personnel of comparable skills, it is probable that only salary rates in the upper steps of this grade are sufficient to obtain the required competence.

It may perhaps be desirable to use this position as a training slot for new, inexperienced professional personnel and hence a requirement of a degree in science or engineering with two years or less of experience might be desirable.

V. Technician (Instrumentation)

Functions and Duties

This position provides operating capability to the Experimental Shielding Facility with emphasis on operation and maintenance of electronic and radiation detection equipment. Incumbent is under direct supervision of the Engineer directing field tests but is himself responsible for proper performance of equipment in his field of competence. Special design or modification of appropriate equipment as required to accomplish specific objectives of a test is the responsibility of the incumbent. He will also perform necessary calibration and operating checks.

Evaluation of Position

Since the success of the experimental operation will depend on proper operation of equipment, and on knowledge of capability, limitations, reliability, and possible modification of equipment to meet necessary requirements, the position requires that the incumbent possess a background of practical experience. A rating of GS-9 would be minimal. Based on industrial experience with personnel of comparable skills, it is probable that only salary rates in the upper step of this grade are sufficient to obtain the required competence.

VI. Laborers

Functions and Duties

As required by the time phasing of the experimental program and under the direction of Engineer directing field tests, laborers (estimated as two men) are needed to perform erection of structures. This will involve lifting by crane or comparable equipment of concrete slabs; placement of masonry blocks, steel guide bars, wood beams and the like; and positioning of equipment. Specifically excluded is handling or operation of radioactive source materials.

Evaluation of Positions

Since the requirement for this service is not continuous but periodic and limited to the times when structures or their components are to be installed or erected, or dismantled, it is suggested that personnel providing such duties be drawn from a labor pool. Permanent assignment of personnel for these duties would be unnecessarily costly and wasteful of manpower.

SECTION 5

EQUIPMENT AND INSTRUMENTS

> Equipment and Instruments: A list of equipment and instruments necessary for the conduct of the experiments and for safety of operating and other personnel shall be prepared in sufficient detail to permit ordering. This list shall include the circulation system, the radioactive sources, various detectors, readout equipment, emergency equipment, instruments for routine survey of the premises, and the storage facility for radioactive materials. The need for detectors shall be made specific so that each contemplated test can be carried out in detail.

The following is a list of equipment and instruments necessary for the successful conduct of gamma radiation experiments. This list is specifically designed for use with the pumped source circulation system. A brief discussion accompanies the more critical equipment and instrument items required.

A suggested scope of work to meet purchase requirements is also presented below.

I. Suggested Scope of Work

The objective of this Purchase Request is to procure a system for the simulation of uniformly contaminated fields of cobalt-60 at the radiation test area of the National Protective Structures Development Center. This area source may be simulated by line or point sources with spacings not greater than 10% of the radius. The development of a system of this type is essential to the further investigation of the shielding afforded by structures from fallout radiation.

The scope of the problem includes the design, fabrication and installation of this system in accordance with appropriate AEC regulations. The test area over which contamination is to be simulated is a 500 x 700-ft rectangular area surrounded by a 1000-ft controlled exclusion area. It is desired that this system have the capability of simulating both a 500-ft radius quarter-circular field and a 200-ft radius semi-circular field, surrounding the test structure. The sources must be sized such that structures of protection factors ranging from one to one thousand may be tested with total exposure of less than 32 hours. No single exposure may require more than eight hours.

Additionally, machine-operated calibration sources of 0.5 and 5 curies of cobalt-60 will be required for calibration purposes.

II. Pumping Console

The pumping system should consist of two pump assemblies, a variable speed drive, electric motors, a storage reservoir, and suitable valves for controlling fluid flow into the polyethylene test loops. The basic pumps should consist of a high-speed pump capable of delivering approximately 600 GPH against a 200 psi head and a positive displacement proportioning type pump. The high-volume pump is mainly for filling of the tubing lengths and for rapid non-positive source or dummy source movement. This pump is also required for emergency operations if a source assembly should become stuck in the polyethylene tubing or associated fittings. The pump should be powered by a 2 HP 220 volt electric motor. To meet the experiment requirements the positive displacement pump should consist of two pairs of pump cylinders coupled for continuous source motion and capable of delivering from 10 to 100 GPH against a maximum pressure of 100 psi. Experience at Technical Operations, Inc. has shown that a Hills-McCanna proportioning pump or equal will give excellent service for these requirements. A 10:1 variation in pumping speed can be accomplished by use of a Reeves (or equal) variable speed drive. This pumping arrangement requires a 3/4 HP 220 volt electric motor. Additional minor variations in pump output are obtainable by adjustment of the pump stroke.

Each pair of pumps will be connected by metal tubing to a solenoid valve, a pressure relief valve, a pressure gauge, and a check valve to form a dependable pumping system for each test loop. The solenoid valve should be wired for remote operation from a control position. The complete pumping assembly except for a water storage container should be mounted on a common base plate.

A water storage capacity in the order of 275 gallons is required for the pumping system. The storage tank should have a visual water level indicator.

III. Tubing, Tubing Reels and Fittings

Approximately 30,000 feet of tubing is required to make up tubing loops for both the quarter- and half-symmetry source areas. It is preferable to have the 30,000 ft of tubing on hand for both source areas each with its own tubing cut to

appropriate lengths. An alternative course would be to obtain tubing only for the quarter-symmetry field, requiring an initial inventory of only 20,000 ft of tubing. This tubing could later be removed from the quarter-symmetry field and cut and spliced as required for the semicircular field. This is not recommended, however, because over-all reliability will be reduced through use of additional coupling needed for complete area fields. The material used to fabricate the tubing could be either linear polyethylene, polyvinyl chloride, or polypropylene. Polyethylene has always been used in similar service in the past due to its relative inexpensiveness and availability; however, it exhibits increased brittleness with age (due to the effects of the ultraviolet portion of the light spectrum), causing a maximum useful life of about one year. This total life may be extended by about a factor of five (to five years) without interfering with the tubing clarity by blending about 1/4 per cent of a product called CYASORB UV 531 (American Cyanamid Company) with the polyethylene prior to extension. This material acts as a screen to filter out the ultraviolet portion of sunlight in the extreme outer layer of the tubing. A similar effect may be obtained by adding 2 to 2-1/2 per cent of carbon black to the tubing mix before extension; however, the tubing is thus rended opaque. Polyvinyl chloride tubing, though somewhat less sensitive to ultraviolet light, becomes extremely stiff and difficult to handle and exhibits "cold memory" of its previous orientation at temperature at or near freezing. Polypropylene offers somewhat increased resistance to ultraviolet damage; however, it is more opaque than polyethylene making it more difficult to locate the source in the event of emergency conditions, is less tolerant to damage by ionizing radiation by a factor of twenty relating to polyethylene and is considerably more expensive (about twice the cost of polyethylene). We therefore recommend that polyethylene with 1/4 per cent of CYASORB UV 531 added be used as the tubing material. Tubing specifications are as follows:

Material:	Union Carbide Co. DFD-0600 mixture polyethylene, or equivalent, with 0.25 per cent American Cyanamid UV 531 added.
Outside Diameter:	5/8 ± 0.020 inch
Inside Diameter:	3/8 ± 0.010 inch

Circularity and concentricity:	Within 0.010 inch
Finish:	As smooth as practical, particularly inside
Clarity:	As clear as practical consistent with extrusion temperature limits
Lengths:	6-5000 ft continuous, defect-free, lengths. Tubing to be wound on suitable reels.

The tubing reels should be designed to fit a reel base. Thus each reel of tubing can be set into the base unit for dispensing the tubing or a full reel can be lifted from the base to make way for an empty reel in tubing retrieval operations. The reel base should have wheels to permit easy transport of the reel units along the paved strip along the side of the test area. A reel in the order of 4 ft outside diameter by 2-1/2 ft inside diameter by 4 ft wide is required for 5000 ft lengths of this tubing. Tubing on reels should be protected from the direct rays of the sun during storage to prevent aging of the polyethylene by ultraviolet light.

Fittings for coupling the polyethylene tubing to the pump console, water supply and source container should be of the non-compression type. Compression types such as Swagelock fittings reduce the inside as well as the outside diameter of the tubing thus increasing the risk of having a source assembly hang up at the fitting, particularly at low flow rates. Special fittings using a rubber O-ring seal and a tongue and groove design for positive alignment giving a discontinuity-free inside diameter are exclusively used on Technical Operations' tube source equipment. The polyethylene tubing is locked to the fittings by serrations plus hose clamps. These fittings should be of stainless steel for corrosion resistance and toughness for long field service.

Approximately 37 fittings are required. Five male source stop fittings are required, one for a spare and four to connect the source container to the pumping system. The stop-type fittings positively prevent the source from entering the source container to pump tubing. Sixteen male tube fittings are required for connection of the tubing field to the source storage container, while an additional eight male and female fittings are also required for coupling lengths of tubing together.

IV. Source Containers

Separate source containers for each isotope type selected should be provided. Each source container, capable of storing two sources (with the exception of the cesium container) shall include two pairs of stainless steel tubes, each with an inside diameter of 3/8 inch. Each will pass through the container near its center, thereby providing shielding for a source within the tube. Shielding shall be such that a source of 1200 curies of cobalt-60 can be stored in any tube with no more than 200 mr/hr radiation intensity on the exterior surface and no more than 10 mr/hr at a distance of 1 m from any exterior surface of the container. In addition, a longitudinal hole should be provided at or near the center of container to allow source field tubing to be pulled through the container. This permits a source solidly stuck in tubing to be pulled inside the container shielding in the event of an emergency. Construction shall meet Bureau of Explosives requirements for shipment. Containers should be equipped with wheels and lifting lugs for ease of movement. The ends of the four stainless steel tubes shall carry suitable fittings to permit rapid and positive attachment of polyethylene tubing, a source clamping device, and source locks, capable of meeting AEC safety standards.

V. Radioactive Sources

Sources recommended for use at the Protective Structures Development Center Radiation Test Facility are given in Section 2. However, the following selection is recommended for initial acquisition and licensing. Note that a 6-curie Co-60 source has been added to increase flexibility, and that values have been rounded off.

600 curie Co-60 tube source

60 curie Co-60 tube source

6 curie Co-60 tube source

5.0 curie Co-60 calibration source

0.5 curie Co-60 calibration source

100 curie Cs-137 source (for use in CD-V-794 Calibrator)

All sources are encapsulated in stainless steel to AEC requirements. Each of the tube source assemblies shall be designed for pumping through 3/8-inch inside diameter tubing. The assemblies shall be provided with a positive seal against the inner wall of the tubing to insure controlled source motion. The assembly should be easily driven by water pressure around bends of 18-inch minimum radius of curvature. There should be sufficient distance between the source capsule and the source assembly clamping region to center the source within its container. A dummy source assembly (identical except without activity) shall be provided for each active tube source to allow checking of each tubing setup with a non-radioactive pumped assembly. The three encapsulated calibration sources should be provided in commercial radiographic equipment with remotely-operated positive controls for exposure and retraction.

VI. Emergency Equipment

Emergency equipment is required to return a source from the tubing field in the event of a power failure, to shield a source solidly stuck within the tubing and to recover a source which has escaped from a tubing circuit. Detailed procedures utilizing the following equipment is covered under Section 9, Emergency Procedures.

In the event of a power failure necessitating shielding a source that had been pumped part way through a tubing circuit, the source may be returned to its container either by operating the pumping system from an emergency power supply or by pushing the source into the container with high pressure gas. An emergency three-phase generator of 5 KVA 220/110 volts AC output would provide standby power for the source pumps and solenoid control valve as well as for the radiation alarms and lights. The second solution, utilizing high pressure gas, could be accomplished by connecting at a 100 psi regulated pressure a 150 cu ft bottle of pressurized nitrogen into the pressure tube to the storage container. The equipment required for this system would be 2-150 cu ft nitrogen bottles (one spare), a gas pressure regulator, and a short length of pressure hose with fittings to couple the regulator output to the pressure tubing leading to the source container. This connection would be made at the pump console.

An emergency hole should be included in each source storage container to permit a source firmly stuck in a plastic tubing to be drawn into the shield by pulling

this tubing through the container until the source is in a shielded position. A mechanical source transfer unit can then be used to transfer the source to its normal position in the storage container.

Lead bricks, canvas bags filled with lead shot or other shielding material may be required for temporary shielding if the source becomes stuck in a tube fitting or in a position such that the tubing containing a stuck source cannot be drawn into the emergency hole in a storage container. Tubing with the contained source can be drawn through a temporary shield until the source is in a shielded position wherein the source can be attached to the mechanical retrieval (transfer) unit for transfer to its normal container. Bags of lead shot would be required for temporary shielding prior to connecting of the retrieval unit to a source stuck in a source container fitting. Canvas bags filled with 25 lbs of lead shot and having a canvas loop at one end for lifting are very convenient for temporary shielding.

Source assemblies lying outside the tubing may be picked up by their magnetic material heads through use of a 150-foot length of light but strong cord with a light-weight, high strength magnet attached at midspan. The retrieved source assembly is dropped source-end first into a portable emergency source container. The container should have a vertical acceptance hole and should have a large funnel to facilitate dropping a source into this hole. Dose rate should not exceed 200 mr/hr on the exterior surface of 10 mr/hr one meter from any exterior surface of the container. When the source assembly is in the emergency container its head should protrude approximately four inches above the container with funnel removed. The emergency source container should preferably be designed with a 1/2-inch i.d. tube, curved to prevent emergence of radiation. Its lower end should include a stop to locate the source, and a connector so that water may be forced into it under pressure. Its upper end should be threaded to receive a 3/8 inch i.d. tubing fitting, thus permitting the retrieved source to be pumped back into its normal container.

Summary of emergency equipment:

5	-	KVA Gasoline-powered generators — 110/220 V, 60 cycle, AC, 3 phase
2	-	150 cu ft nitrogen bottles
1	-	High pressure gas regulator
1	-	Adapter assembly for connecting gas supply to tubing (valve, hose with connectors)
1	-	Emergency source container capable of receiving 600 curies of cobalt-60 or 2200 curies of iridium-192
1	-	Funnel matched to emergency container
1	-	Lightweight, high strength magnet — 1/2 lb. weight, or less
1000'	-	1/8-inch nylon cord
100	-	2 x 4 x 8 lead bricks, or similar shielding material
25	-	Canvas bags filled with 25 lbs of lead shot (Canvas handle on one end of each bag.)

VII. Radiation Instruments for Experimental Measurements

A. Radiation Detectors

Non-self-reading integrating ionization chambers are the best all-round radiation detectors for use in measuring the gamma ray dose rate within the experimental structures. These dosimeters will integrate the radiation dose produced by a source passing through the polyethylene tubing and forming a source field. 200-mr detectors are used primarily above ground level while for below-ground areas 10-mr detectors will give accurate readings between 1 and 10-mr. Readings below 1-mr should be discarded as accuracy is seriously reduced by radiation background levels and instrument leakage especially during long exposures. Above-ground

radiation dose can in general be measured with 200-mr detectors using the source strengths, fields and structures contemplated. Occasionally low level dose rate regions above ground level will require utilization of the 10-mr detectors.

A total of 400 200-mr dosimeters and 180 10-mr dosimeters are recommended for use in conducting the proposed experimental program. The number of detectors required for planned experiments is based on placing dosimeters at four heights and five positions within each module of the structure with a 50% surplus to allow for dosimeters that have deteriorated or for obtaining greater detail in dose distribution. Thus on each floor there are 6 - 12 x 12 modules with detectors typically arranged at the 1-, 3-, 5- and 7-foot levels at the center and near the four corners of each module. Our experience has shown that the Model 239 Victoreen 0 - 0.01 Roentgen Stray Radiation Chamber and the Model 362 Victoreen 0 - 0.2 Roentgen Pocket Chamber Dosimeter are well suited to this type of experimentation. Quartz fiber dosimeters are not air equivalent and will not produce acc e experimental measurements. Compact, portable, eyestrain-free reader-charger equipment is recommended for daily readout of a large number of instruments. It is further recommended that each chamber model be purchas n a matched lot to eliminate variations in detector performance due to manufacturing tolerance variations between production runs. Dosimeters should all be from the same production run and matched to give the identical performance within ± 2 per cent limits. If the order for these dosimeters should be split with acquisition of part of the units to be made at a later date, then arrangements should be made with the vendor to reserve matched dosimeters for the remainder of the units required.

B. Reader-charger for Radiation Detectors

Four reader-charger units are required for the 10-mr and 200-mr dosimeters used to measure radiation doses within the experimental structures. There should be two units for reading and charging the 10-mr dosimeters and two for the 200-mr dosimeters. The second unit must be available as backup in case the first unit becomes inoperable. Often all four units will be utilized by two data teams reading and recharging the dosimeters in the structure. Extensive field experience has shown that the only suitable method of reading, charging and replacing dosimeters efficiently with a minimum of bookkeeping effort is to use compact, light-

weight portable units that will read and charge dosimeters in one operation on site. With field-type portable units the data team reads the dosimeter at or near its respective position in the test structure, records the reading and replaces the dosimeter for the next exposure. Using non-portable readers requires that all exposed dosimeters be returned to a fixed reader-charger location with extensive bookkeeping procedures to keep track of readings versus both position and detector number and to insure that the same detector is returned to its original position.

Summary of recommended radiation detectors for use in measuring dose levels with experimental structures follows:

- 480 - Victoreen Model 362 Dosimeters — range 0 - 0.2 r
- 180 - Victoreen Model 239 Dosimeters — range 0 - 0.01 r
- 100 - Victoreen Model 208 Dosimeters — range 0 - 1 mr
- 2 - Technical Operations Portable Field-Type Reader-Chargers, for 0 - 0.2 r dosimeters
- 2 - Technical Operations Portable Field-Type Reader-Chargers, for 0 - 0.01 r dosimeters
- 2 - Victoreen Model 687 Minometer II — range 0 - 200 mr.

VIII. Radiation Survey and Monitor Instruments

Survey Meters

Survey meters are required for use by test personnel both in performing and monitoring the experimental operations and for surveying the radiation levels at the exclusion fences. The most critical survey requirements are for test personnel surveying while performing operational procedures and emergency operations. In our experience in radiation test work as well as in industrial radiography, the most versatile and rugged unit having the necessary sensitivity, accuracy, and speed of response is the Victoreen 592 Survey Meter. This unit has a range from 0 to 1 r/hr in three steps: 0 to 10-mr, 0 to 100-mr and 0 to 1000 mr/hr. The unit is compact and shock resistant. The operator can shift rapidly from one scale to another as required for accurate monitoring between 1 mr/hr and 1 r/hr. Test operations require monitoring in all three of these ranges using one compact unit that can be carried in one hand. A minimum of three Victoreen 592 survey meters or equivalent is required. At least two are required for any radiation monitoring

of test operations by operating personnel and at least one spare, preferably two, are required for standby. Four Victoreen 592 survey meters, or equivalent, are recommended for use by test operations personnel. In addition, a CDV 700 (.5 to 50 mr/hr range) should be available for the outer exclusion fence and exclusion area surveys. A CDV 720 (0-5, 0-50, 0-500 r/hr) should be available for high level emergency conditions.

Automatic visual radiation alarms should be strategically placed to warn personnel both inside and outside of the exclusion area of the presence of radiation. These alarms should be used both for general area warning purposes and also to give added monitoring coverage to test personnel while working in or near the test area. For instance, a visual gamma alarm placed near a source container and within view of the operator preparing for an exposure will warn him immediately of a radiation field of even a few mr/hr. He might have missed this on his survey meter because he was concentrating on his work and the field might not have been strong enough to be detected by his partner monitoring him fro[illegible] t away. Experience has shown that at least one gamma alarm or similar vi[illegible]ion alarm should be at the disposal of the operators for placement near source containers while preparing these for operation and for storage. One gamma alarm should be available for the operators in the immediate test area. Two other alarms should be mounted near the test area in a manner such that at least one is readily visible from any part of the inner exclusion area and from the control bunker area. These alarms should be of a type that present a visible "safe" warning at radiation levels less than 2 mr and give a visual emergency signal at higher levels. There should also be a gamma alarm inside the control bunker for personnel safety to indicate when the level exceeds a preset 2 mr level. A gamma alarm mounted on the observation tower or other elevated position near the control bunker indicates to the operating crew whether the source is out or not. This alarm should also control at least two flashing red lights at each of the two inner exclusion fence gates, as well as for two outer exclusion fences. One gamma alarm should be available for standby use. These visual radiation alarms should be similar to the Technical Operations, Inc. Model 492, or equivalent, weathertight, have a green light for safe operation and flashing red for radiation indication, and contain a slave relay so that additional red lights, timers and/or audio alarms may be controlled by the device.

Summary of survey and dose rate instruments required:

3 - Victoreen 592 Survey Meters (0-10, 0-100, 0-1000 mr/hr)

2 - CDV 700 Survey Meter (0.5 to 50 mr/hr)

2 - CDV 720 Survey Meter (0-5, 0-50, 0-500 r/hr)

7 - Technical Operations, Inc. Model 492 Gammalarms

Approximate cost, excluding OCD items, is $4000.

IX. Miscellaneous Equipment and Instruments

Dosimeters and chargers:

200 - CDV-138 dosimeters (0-200 mr)

12 - CDV-730 dosimeters (0-20 r)

6 - CDV-740 dosimeters (0-100 r)

4 - CDV-750 chargers

1 - Gamma Radiation Recorder, to give continuous record of operations at the site. Also is very useful to operating personnel in following source movements through the tubing.

1 - CDV-794 Calibrator, complete.

1 - 20-power spotting scope with mount for tubing, source and area inspection from a safe distance.

1 - Barometer.

4 - Thermometers — one for each level of the test structure and one for outside temperature.

1 - Simpson Meter Model 260, or equivalent, for battery checks of survey instruments and instrument maintenance.

1 - Radiation detector drying box with silica gel as the drying agent. The 10-mr and 200-mr dosimeters for experimental use should be stored in the presence of a drying agent when not in use in order to obtain optimum detector performance.

Dosimeter mounting material — The simplest method of mounting large numbers of dosimeters within a structure is to staple paper cups to thin vertical strips of wood. These strips can then be "sprung" in place between floor and

ceiling at the proper locations. Wooden strips in the order of 1/4 in. x 2 in. cross section are most useful for this purpose. Dosimeters are easily dropped into the cups or removed for reading during experiments. The wood in the vicinity of the detectors is kept to a minimum to prevent perturbing the radiation field. A good supply of wood strips or slats, paper cups, and masking tape should be available and are the most useful items in constructing dosimeter stations.

Other tools and material found necessary for operation and maintenance of the facility and equipment are:

Spare instrument batteries
100' roll .006-inch thick by 12 ft wide polyethylene sheet
6 Flashlights
Propane torch and cylinders
2 - Stop watches
Electric timer
Tool box
Screw Driver set
Knife
Prick punch
Open end wrench set
Cold chisel
Ball peen hammer
Combination square
14-inch pipe wrench
Soldering kit
Pliers — cutting
Pliers — angle
Sufficient methanol-type antifreeze for pumping system
Appropriate foul weather clothing
2 - 100-foot measuring tapes
Yard sticks
2 - 6-foot measuring tapes
Miscellaneous string, rope and wire

Pump lubricants

Extension cords

Clipboards

Stakes for marking tube locations and distances

Spray paint for marking

Acetone for cleaning instruments.

The estimated approximate costs for this miscellaneous equipment excluding that equipment which may be directly supplied from the Office of Civil Defense is $1,000.

SECTION 6

CALIBRATION AND MAINTENANCE OF INSTRUMENTS

Calibration and maintenance of instruments. Such calibrations will involve the use of special sources to determine the sensitivity of the equipment used in the experimentation. Calibration shall be done using the test sources themselves. Calibration of the Facility to establish reference data shall be planned. Maintenance procedures for equipment shall include not only the test detectors and readout equipment but also the survey instruments used for safety applications.

Calibration of Instruments

The instrumentation required in the operation of the radiation test area of the Protective Structures Development Center are divided into two categories for purposes of discussion. These are instrumentation to be used to obtain direct measurements during experimentation and survey equipment designed to protect the operators of the experiment. Since the value of the experiments to be performed is only as good as the data obtained, more rigorous standards of calibration of equipment must be imposed upon the former category of equipment than the latter. Thus, two methods of calibration are proposed.

Experimental Equipment

The fundamental radiation detection devices proposed for use are non-self-reading ionization chambers and associated charging and readout equipment. Calibration of these devices with a standard radiation source is periodically required to determine if shifts in the reader-charger calibration have occurred and to evaluate dosimeters suspected to be producing erratic readings. Because of the recurring nature of calibration requirements we recommend that primary and secondary methods of calibration be used.

The primary calibration, discussed more fully under the heading Experimental Program, consists of an essentially free-field measurement designed to determine only the direct radiation from the standard sources, while the secondary calibration is based upon the measurement of direct and scattered components. This secondary calibration consists of constructing a permanent range, with instru-

ment and source positions fixed, and calibrating the range using the results obtained from the primary free-field measurement. Once calibrated, the dose distribution over the range remains fixed and the dose rate varies only by the decay of the calibration source.

We have found in our experience that machine-operated (remote control exposure) sources capable of producing fields of 5-15 R/hr at one foot distance are most useful for these purposes. However, if use is made of an isotope of short half-life for a calibration standard, these values should probably be exceeded so that the standard source may be used over a larger period of time. We thus recommend standard sources of 1/2 curie of cobalt-60, 1 curie of cesium-137 or 2 curies of iridium-192 depending upon the isotope used in the main experimentation.

Survey Equipment

The equipment types required for general survey work at the radiation test site are the CDV-700 0-50 mr/hr, the CDV-720 0-500 R/hr, and the Victoreen Model 592 0-1 R/hr survey meters. The exact calibration of these instruments is not critical as they will not be used to obtain direct experimental data. Calibration may thus be performed on the secondary calibration range constructed for the experimental equipment (see above), or the CDV-794 Instrument Calibrator. Each method of calibration exhibits certain advantages. The use of the secondary range provides an essentially infinite variety of dose rates between certain broad limits for calibration purposes; however, the maximum values available, set by the ranges of the experimental equipment, are of the order of 1 to 5 R/hr. The CDV-794 Instrument Calibrator provides high maximum dose rate (100 R/hr) but is limited to providing only 8 submultiples of this dose rate.

Maintenance of Instruments

Maintenance procedures for each of the instrument and equipment types are adequately covered in the civil defense maintenance procedures and manufacturers' literature provided with each item and hence are not covered in detail here. The equipment required for maintaining consists of the usual assortment of small hand tools, soldering gun, battery tester, voltmeter and a small 5 to 30 millicurie source similar to the CDV-784 Training Source to cause the instrument to respond such that circuit checks may be made.

The only routine maintenance that we have found required with the aforementioned experimental equipment is a weekly check of battery strengths (voltage under load) and cleansing of the dosimeters and dosimeter socket in the reader-charger. Battery voltage should be maintained at 95% of rated voltage or better. When voltages drop below this value they should be replaced with fresh batteries. The dosimeters should be cleaned by washing the electrode end in acetone when they exhibit leakage greater than 1 per cent in ten hours. Similarly, the dosimeter socket in the reader-charger should be cleansed with a "Q tip" or similar instrument and acetone at regular intervals depending on the amount of dust and dirt collected in the socket.

SECTION 7

SOURCE FIELD PARAMETERS

Parameters for laying out source tubing. These shall include such factors as source speed, pump pressure, tube length, tube spacing, rate of pumping, and shall be so displayed that operating personnel can readily set up appropriate experimental layouts.

The object of the source circulation equipment is to create a simulated uniform field of contamination. This objective is achieved by causing the source to spend uniform amounts of time in each unit area of the field to be simulated and summing the results from each unit area through the use of detectors that will integrate the dose over the total exposure time. This is done by pumping the source at constant velocity through tubing placed to uniform density. The simulated source density of the field in effective curies per square foot is thus the product of the source strength in curies multiplied by time of exposure divided by the area simulated.

The accumulated dose within a structure about which the area is simulated may thus be written as

$$D = \frac{FI_oST}{AP_f} \qquad (1)$$

where

D	=	Total accumulated dose
I_o	=	The dose rate 3 feet above an infinite field of density 1 curie/ft^2 = 497 R/hr for cobalt-60, 137 R/hr for cesium-137, ~ 185 R/hr for iridium-192
S	=	The source strength in curies
T	=	Exposure time, hours
F	=	The fraction of infinite field represented by the experimental area
A	=	Area of the simulated field (ft^2)
P_f	=	The protection factor afforded by the structure from ground-based sources of radiation.

The fraction of infinite field dose for any annulus may be obtained from Figure 6, a plot of the fraction of infinite field dose versus radius, by taking the difference of the two readings corresponding to the inner and outer radius of the annulus.

The exposure time, T, which equals the length of tubing divided by the source velocity, may be set anywhere within certain broad limits imposed by the capabilities of the pumping system. The pumping system is capable of providing metered flow of from 10.2 to 102 GPH, equivalent to source velocities of 1000 to 10,000 ft/hr against a maximum operating head of 100 psi. Since the operating pressure is dependent upon both the velocity and the length of tubing used, the maximum possible exposure time may be computed from the pressure drop characteristics of the tube for each velocity. Figure 7 is a plot of the pressure drop per thousand feet of tubing. The maximum exposure time calculated from the 100 psi pump limitation versus the source velocity is shown in Figure 8 as a limiting curve.

The use of the aforementioned equations and charts is perhaps best illustrated by an example. Consider the problem of designing a quartercircular simulated field of cobalt contamination capable of measuring test structures of 24 x 36 ft floor plan, with protection factors varying from one to a thousand. Since it is impossible to create a simulated contaminated field of infinite radius, it is desirable to divide the actual field to be simulated into annular rings such that an estimate of far-field radiation may be made. Past experience has shown that four annular areas are sufficient to perform this extrapolation. The maximum radius of the quartercircular field that may be simulated in the existing facility is 500 feet while the minimum radius of 16.6 ft is that of a cleared circle whose area equals the floor plan area.

Returning to Figure 6, it is found that a full annular field of these dimensions would represent 58 per cent of an infinite field. However, since we are concerned with a field of quarter symmetry only, the total field represents 1/4 of this, or 15 per cent, and each of the four experimental areas one quarter of this, or about 4 per cent of infinite field. The radii of each experimental area as determined from Figure 6 are presented in Table II.

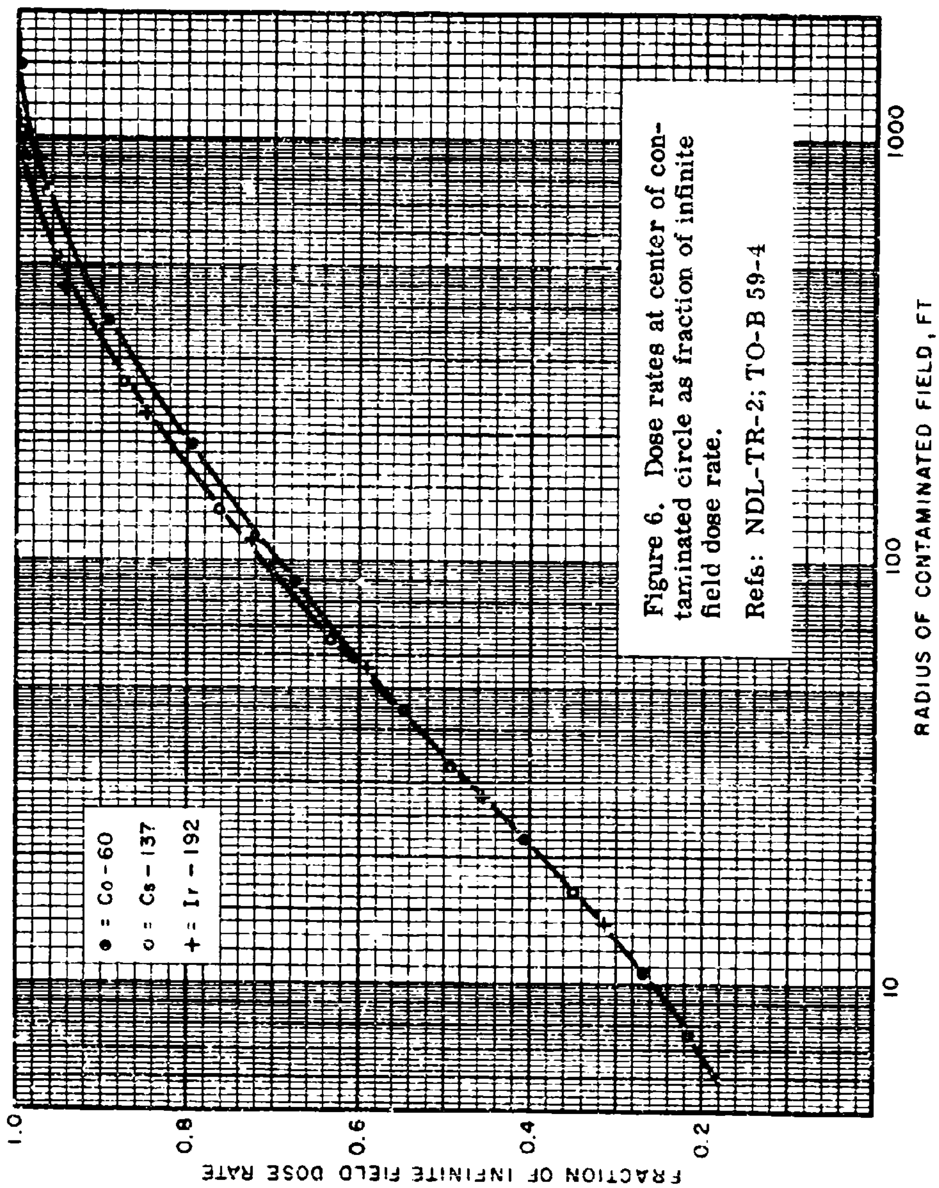


Figure 6. Dose rates at center of contaminated circle as fraction of infinite field dose rate.

Refs: NDL-TR-2; TO-B 59-4

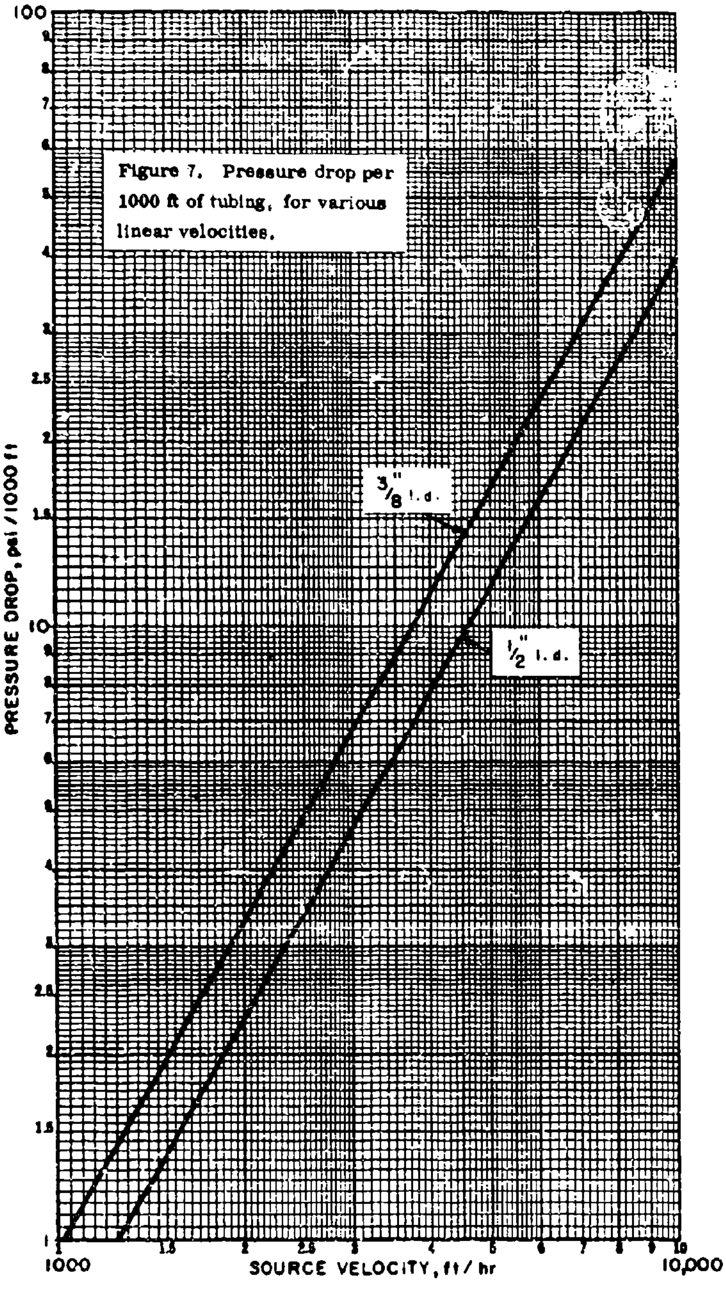


Figure 7. Pressure drop per 1000 ft of tubing, for various linear velocities.
3/8" i.d.
1/2" i.d.
PRESSURE DROP, psi / 1000 ft
SOURCE VELOCITY, ft / hr
1000
10,000
100
10
1

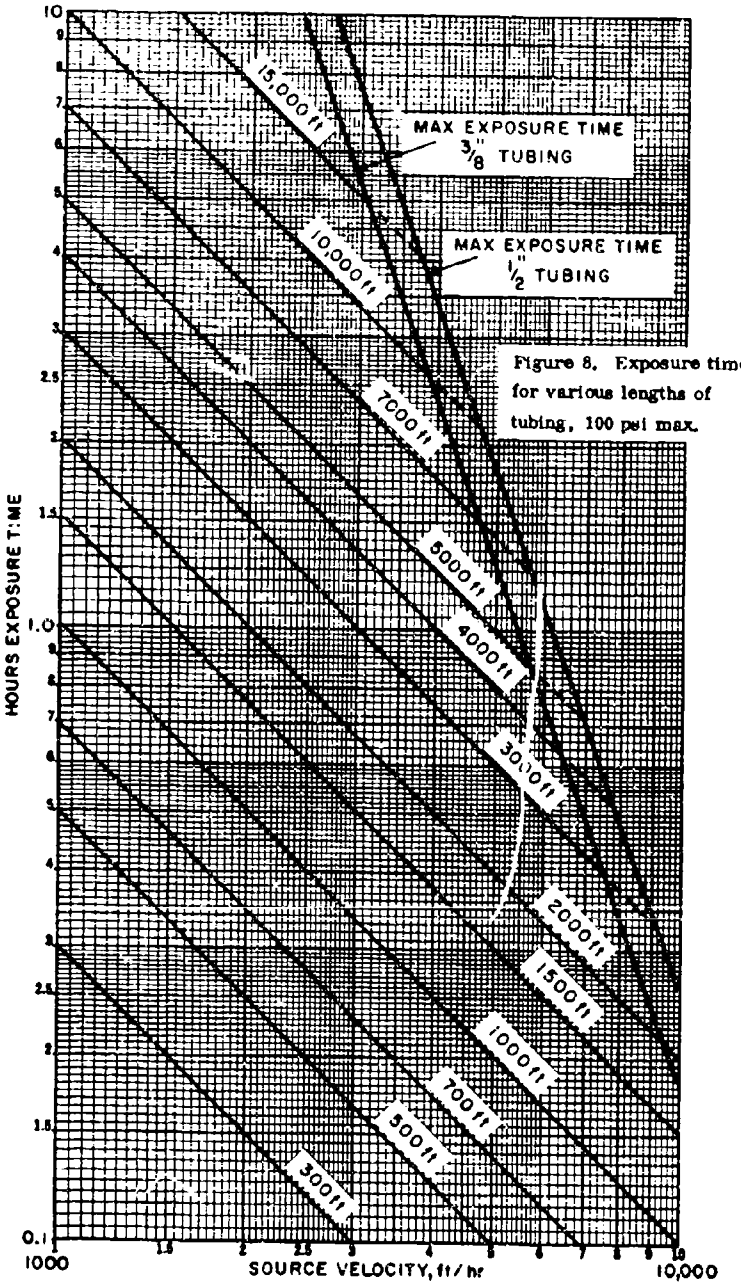


Figure 8. Exposure times for various lengths of tubing, 100 psi max.

TABLE II

EXPERIMENTAL QUARTER CIRCULAR AREAS

	Inner Radius (ft)	Outer Radius (ft)	Area $(ft)^2$
Area 1	16.6	35	750
Area 2	35	75	3,460
Area 3	75	170	18,300
Area 4	170	500	174,000

Since the field is designed to measure structures of varying protection factor, the minimum and maximum range of expected protection factor, available instrumentation, pump capabilities, and source sizes place limits upon the exposure times and hence the lengths of tubing required. Consider first the case of the lightly-protected structure with P_f equal to unity. To insure maximum flexibility of the facility we wish to utilize the highest range detectors, the highest source speed and the minimum source size. Since 200-mr detectors are the largest available and we do not wish to exceed 90 per cent of this value, or 180 mr, and the 60 curie cobalt source is the smallest tube source available, the required exposure time, T, may be calculated from Equation (1) as

$$T = \frac{DAP_f}{FI_oS} = \frac{0.18 \times 750 \times 1}{.04 \times 497 \times 60} = 0.10 \text{ hour.}$$

Similarly, for the case of $P_f = 1000$ using 10 per cent of full range of the most sensitive chamber available, or 1 mr, and the largest source of 600 curies,

$$T = \frac{DAP_f}{FI_oS} = \frac{0.001 \times 750 \times 1000}{.04 \times 497 \times 600} = 0.06 \text{ hour.}$$

From Figure 8 it may be seen that the length of tubing that may be placed in the innermost experimental area ranges from 100 to 1000 feet for the case of $P_f = 1$ and from 60 to 400 feet for the case of $P_f = 1000$. Therefore, any tubing length between 100 and 400 feet may be placed in this first experimental area.

Similar computations may be performed in turn for each of the simulated areas. The required tube spacing may then be obtained by dividing the area of the simulated field by the length of the tubing. For example, if a tubing length of 375 feet is selected, the tube spacing would be equal to

$$\text{Tube spacing} = \frac{\text{Area of simulated field (ft)}^2}{\text{Required length of tube (ft)}} = \frac{750}{375} = 2 \text{ ft}$$

SECTION 8

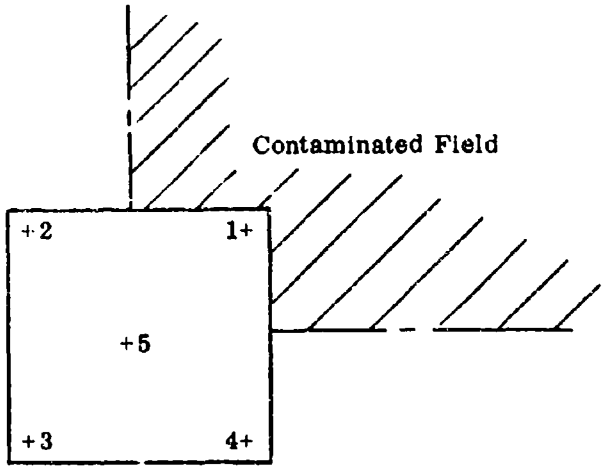
EXPERIMENTAL DESIGN

Experimental design shall indicate how experiments may be conducted to produce reliable readings on integrating detectors. Descriptions of the uses of symmetry shall also be included.

In performance of experimentation upon test structures at the radiation test facility it is necessary to first determine if structural symmetry exists. This may be done by proper examination of the proposed floor plans. If neither quarter- nor half-symmetry exists, minor modification of this floor plan will be required. Once the symmetry of the structure has been developed, selection may be made of instrument positions to measure the desired dose distribution. These positions must be arranged such that instruments to the left of the line or lines of symmetry are mirror images of those to the right.

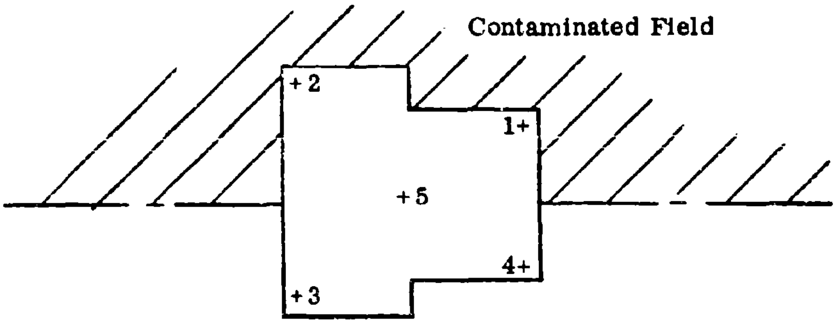
This type of instrument arrangement is required if symmetry is to be used in order that the estimate of effects of a test field surrounding the entire structure may be made by adding the data taken from symmetrical positions (see Figure 9). Once structure design and instrument locations have been "frozen," estimates of the protection factors at each position may be made using the manual entitled "Design and Review of Structures for the Protection from Fallout Gamma Radiation." These estimates may then be used in the design of the required test field in a manner similar to that described in the previous section entitled Source Field Parameters. It should be cautioned that to insure reliable readings from the ionization chamber detection equipment, the experiment should be designed such that readings are expected to fall between 10 and 90 per cent of full scale of the instruments selected and should be at least a factor of ten above the natural background rate of approximately .01 mr/hr.

An additional fact that must be considered is the choice of tube spacing. The most desirable tube spacing for any given experiment may not be that as selected in Section 7 as a problem arises if the spacing is so great that the field no longer appears uniformly dense.



Full field results are obtained by adding values obtained from positions 1, 2, 3 and 4, for the corner position and by multiplying the center position, 5, by four.

QUARTER SYMMETRY



Full field results are obtained by adding values obtained from position 1 and 4, for right corner positions, 2 and 3 for left corner positions and multiplying position 5 by two for central positions.

HALF SYMMETRY

Figure 9. The Uses of Symmetry.

This effect will appear as an error in the measured vertical dose rate distribution near an aperture. The spacing requirement can be made quantitative as follows (see Figure 10): at any given detector position specified by its horizontal distance x from the aperture and its height h above the sill, let r_o be the distance to the nearest tubing on the ground that can be "seen" by the detector. Then if y is the sill height above grade, the spacing of tubing at this point should be less than $r_o^2\Delta h/xy$ where Δh is the desired detector vertical spacing in the vicinity of the particular detector. When the spacings are as given, at least one more turn of tubing will be "seen" by the upper detector than by its next lower neighbor.

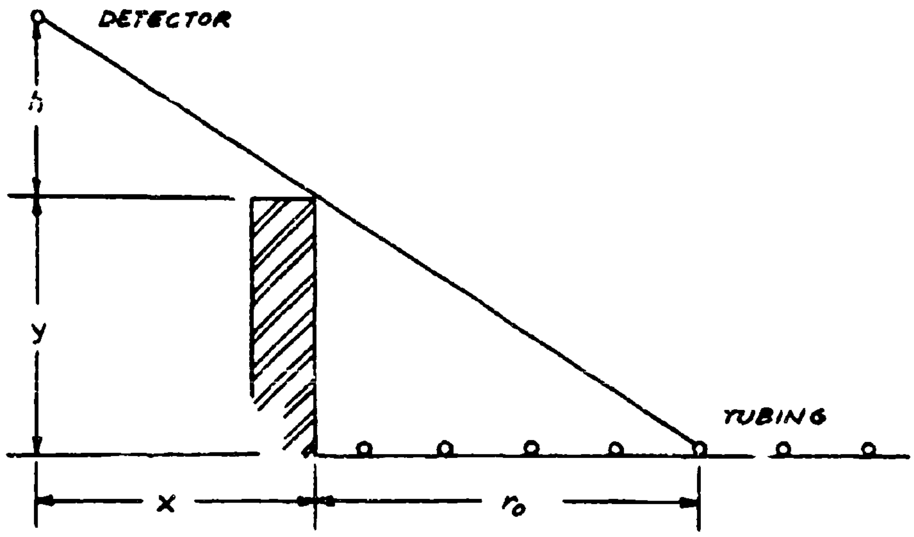


Figure 10. Tube Spacing

SECTION 9

DETAILED OPERATING PROCEDURES

> <u>Detailed operating procedures for the tests.</u> A check list shall be made for initial checkout and for steps to be taken in exposing and securing the traveling source or any fixed sources used. The contractor shall develop detailed procedures to cover accidents and incidents. Procedures shall include equipment that will permit field expendiency to be devised for accidents and incidents not covered specifically.

<u>Detailed Operating Procedures</u>

A step-by-step presentation of experimental operating procedures is here presented. These procedures have been developed over a period of years based upon a general philosophy of minimum exposure and maximum safety to the source operators. The steps are arranged in sequence such that operations may be stopped at any step and return to initial conditions quickly and easily achieved.

1. Clear the experimental and exclusion area of non-operating personnel, notify guards that a test is about to begin, and check to insure that all access gates to the radiation test facility are locked.
2. Check to be sure that all operating personnel are equipped with film badges and personal dosimeters.
3. Select and preset circulating pump speed.
4. Place the dummy source capsule in the tubing array to be used for the experiment.
5. Connect pump leads to the tubing array.
6. Start circulating pumps.
7. Energize solenoid valve directing flow from return to reservoir to the selected experimental area.
8. Observe the movement of the dummy source to ascertain that the tubing has not been inadvertently damaged.

9. At the conclusion of the "dummy test" de-energize the solenoid valve, shut pumps off, and remove dummy source from system.

10. Charge instruments and place in their proper locations in the test structure.

11. Place the proper (cobalt, iridium or cesium) source storage container in proper location to be connected to the appropriate test area.

Note: Steps 1 through 11 are to insure that the tubing has not been damaged, safety regulations have been met and the experiment is properly set up. Steps 12 through 26, the active or "live" portion of the operation, should be performed by a team of two operators — one to perform the operations, the other to monitor the performance from a distance of about 50 feet; each operator must be equipped with a radiation survey meter and the operator working directly with the source should have a visual radiation warning device such as the Tech/Ops Model 492 Gammalarm in direct view at all times, as it is difficult to perform the required operations and watch a survey meter at the same time.

12. Select either the large or small source to be used. Be certain that source is clamped, remove shipping plugs, unclamp source and pull the desired source assembly from container a distance of approximately 1 inch and reclamp. Inspect the source piston leather and replace it if required.

13. Connect tubing from field to source storage container and from the storage container to the return line to the pump console.

14. Connect pressure lead from pumps to rear of source assembly.

15. Unclamp source assembly.

16. Retire to pumping console, start pumps.

17. Retire to the solenoid switch control and operate solenoid valve (key lock switch).

18. Wait until exposure is complete and source has returned to storage container.

19. Return solenoid valve (key lock switch) to OFF position (pilot light on).

20. Turn off all pumps.

21. Approach storage container using hand-held survey meters, and clamp source by tightening source clamp.

22. Disconnect pressure tube from source storage container; allow 5 minutes for pressure to bleed down.

23. Disconnect all remaining tubes from the storage container and insert shipping plugs.

24. Replace padlocks on shipping plugs.

25. Read out instruments.

26. Return to Step 1 for next run.

Emergency Operations

Almost any credible kind of accident with the radioisotope equipment used at the radiation test facility may be rectified or placed in safe condition by the application of two simple rules.

The first rule, one of paramount importance, is to never attempt to operate, repair or service any isotope equipment unless you have a radiation detector that works, a film badge, and personal dosimeter.

The second rule is THINK! — think out to completion the steps you must take to remedy the trouble. Estimate the time each step will take, estimate the radiation level you will be exposed to during each step, and compute your total expected dose. Don't assume at this point that because the total is less than your permissible dose you should proceed. Re-evaluate the plan to minimize your exposure. Is it possible to take advantage of even partial shielding? Question your plan to make sure you are not taking a step where failure would complicate your problem. Think, and do your thinking outside the radiation area. Most over-exposures are unnecessary and are the result of hasty action and lack of thought.

A few of the routine steps used to solve emergency conditions are listed in step fashion below.

EMERGENCY PROCEDURES

DUE CAUTION MUST BE EXERCISED TO MINIMIZE TOTAL ACCUMULATED DOSAGE TO OPERATORS DURING ALL FOLLOWING PROCEDURES.

1. In case of power failure, the following solutions are listed in order of decreasing preference. Note: Solenoid valve is closed to the source tubing loop (in OFF position) without power:

   Solution A — Emergency generator

   Close solenoid valve (key lock switch); connect the emergency generator to the pumping console. Turn on high-speed gear pump. Retire to location of solenoid switch; turn on switch. After source has entered its storage container, complete Steps 12 through 17 of Normal Operating Procedure.

   b. Solution B — Using nitrogen gas pressure

   Connect gas bottle to pumping console with pressure regulator provided. Open gas bottle. Set regulator between 50 and 100 psi. Retire to location of solenoid switch. After source has entered its storage container, shut off gas supply and repeat Steps 12 through 17 of Normal Operating Procedure. Caution: When disconnecting tubing, disconnect pressure tube to storage container first. Allow a minimum of 15 minutes for gas pressure to bleed down.

   c. Solution C

   Use any applicable emergency procedures described below.

2. In the event that the source sticks in the experimental circuit of tubing, the following procedures are to be used in decreasing order of preference:

   a. Solution A

   Turn off solenoid valve (key lock switch). Turn on high-speed gear pump. Retire to location of solenoid valve switch

and turn switch on. After the source has returned to its storage container, complete Steps 12 through 17 of Normal Operating Procedure.

b. Solution B

In the event that Solution A is unsuccessful, repeat Solution A but reverse leads on the pumping console such that the pressure lead is connected to the reservoir return and the reservoir return line is connected to the pump pressure outlet. This places water pressure on the opposite side of the source assembly. Repeat Steps A and B several times.

c. Solution C

In the event Solutions A or B are not successful, turn off all pumps and solenoid valve. Remove lead plug from the emergency tube of the source storage container. Cut tubing at nearest possible position to source and draw tubing through container until source is shielded. Note: The emergency hole in the storage container will not allow the passage of fittings. If the source is stuck in a fitting, construct a temporary lead shield 6 inches thick over the tubing and draw tubing through this shield until the source is shielded. Cut tubing such that the source piston is exposed. Install the braided stainless steel retriever cable through storage container tube. Connect the male end of the cable to the piston end of source and draw into storage container. Clamp source and insert shipping plugs.

3. In the event the source sticks while entering the shipping container, the following procedures will be used:

a. Solution A

Try all applicable solutions mentioned above.

b. Solution B

Pile bags of lead shot on the storage container over the source. Caution: Proceed to minimize total radiation exposure. Continue

piling bags of lead shot over the source until the radiation level is reduced below 200 mr/hr. Remove the hose on the opposite end of the tube in which the source is stuck. Install the braided stainless steel retrieval cable. Twist this cable until it engages the threads in the nose portion of the piston assembly. Pull source into storage container. Tighten source clamp, disconnect cable, and insert shipping plugs.

4. In the event the source emerges from the tubing, the following procedure is to be used:

   Insert funnel in top of Emergency Storage Container. Attach magnet to center of 150 ft of nylon cord. Using two operators, one at each end of cord, pick up source with magnet (only piston end is magnetic, so that the hot end of the source will hang down). Drop source into funnel in emergency storage container. Install screw fitting over protruding piston head, making sure that piston leather is in good condition. Attach hose from high pressure pump to fitting at base of storage container. Connect tube between screw fitting atop Emergency Container and input tube of normal storage container. Apply pressure to drive source through this tube. Tighten source clamp and install shipping plugs.

DUE CAUTION MUST BE EXERCISED TO MINIMIZE TOTAL ACCUMULATED DOSAGE TO OPERATORS DURING ALL FOREGOING PROCEDURES.

SECTION 10

ROUTINE PERSONNEL OPERATING PROCEDURES

> Procedures shall be established for determining the safety of the premises at any time, for leak testing of all sources, for emergency conditions, for personnel dosimetry, for safe conduct of visitors, and for maintaining records and reports related to radiation testing. Requirements for individual workers imposed by the AEC, and the duties and qualifications of the health physics officer and of the safety officer shall be established.

Routine operating procedures other than the specific operations required to perform each experiment are required for successful operation of the facility. These procedures relate to the keeping of records on personnel exposure and experimentation, the duties of the assigned Health Physics Officer and the conduct of visitors through the facility.

Record Keeping

The record keeping requirements of a radiation test facility are best kept in daily operating log form. Three separate documents are required: an exposure log, an experimentation log, and a calibration log. All records with regard to personnel exposure, dose rates at the exclusion fence and source leak checks are to be kept in appropriate portions of the exposure log. A daily entry of all experimentation including source type, size, and a brief description of the experiment performed and the total exposure time of the source should be made in the experimentation log. It is in general normally convenient to collect all calibration data relating to the experiment in a single log. Therefore, it is suggested that a detailed description of all calibration experiments performed and their results be entered in the calibration log. For purposes of clarity, it is suggested that all of these logs be kept in ink and transcribed at regular intervals to typewritten pages.

Staff Operating Personnel

All members of the staff that routinely or occasionally participate in experiments at the radiation test area shall be issued film badges weekly and personal dosimeters. These must be worn at all times when working inside the outer exclusion fence. Personal dosimeters will be charged at the beginning of each day

and their reading entered in the "Exposure Log" at the conclusion of each day. As film badge readings are obtained these should be entered in the exposure log. Any incident involving even minor over-exposure of personnel will be written up, signed by the individual involved, and entered into the permanent exposure log on the day of the incident. AEC Regulations (Section 20.101) permit a maximum whole body exposure of (N-18)5 rem in any twelve consecutive months (where N is the individual's age in years), or 3 rem in any calendar quarter, if the exposures are reported on form AEC-4 to the Atomic Energy Commission. Thus, operative personnel should not receive on the average over 100 mr per week during normal operations. Previous experience with equipment of this type indicates that operator dose rate is generally below 50 mr/week. Maintenance of the permanent exposure log should be the responsibility of the Health Physics Officer. Routine surveys to the maximum dose rate measurable at the outer exclusion fence will be made and entered in the appropriate portion of the exposure log. Monthly examinations of all tube sources for leakage shall be made by removing 5 cc of water from the source storage tube and measuring its activity. This value shall be recorded in the exposure log. If this activity exceeds .005 microcuries, the source will be returned to the manufacturer for repair.

Health Physics Officer

The routine duties of the Health Physics Officer will be to

1. Instruct personnel in the rules and regulations of the Atomic Energy Commission with regards to the proper handling of source materials.

2. Review the exposure log weekly to insure against over exposure in any reporting period weekly, quarterly or yearly.

3. Make periodic surveys of the dose rate at the exclusion area fence.

4. Make periodic surveys of the operational procedures used during performance of the experimentation.

5. Be responsible for periodic leak checks of all sources stored at the facility.

6. Shall maintain records showing the radiation exposure of all personnel exposed to radiation. These persons are defined as any individual who enters a restricted area under such circumstances that he receives or is likely to receive a whole body dose in excess of 300 millirems in any calendar quarter, or any person who enters a high radiation area.

7. The Health Physics Officer shall see that Occupational External Radiation Exposure Histories for each employee are on file and available to employees on reasonable demand.

8. The Health Physics Officer shall conduct surveys or inspections on an unscheduled basis to insure compliance with these instructions, with 10 CFR 20, 30, and 31.

9. The Deputy Health Physics Officer shall assume the duties of the Health Physics Officer when the latter is absent.

Visitors

The admittance of visitors to a facility of this sort during active experimentation is highly undesirable. However, it is recognized that under certain circumstances it is unavoidable. Visitors are best handled by keeping a visitor's log and issuing each visitor a film badge and a personal dosimeter before entrance beyond the outer exclusion fence. During time of actual experimentation each visitor should be accompanied by a radiation worker carrying a survey meter.

SECTION 11

TRAINING REQUIREMENTS

Training. The basic material to establish a training program shall be developed, to qualify and maintain qualifications of permanent PSDC staff personnel in handling radioactive sources and in related activities.

Since the radiation test facility is a research facility it may be assumed that the senior personnel assigned to it will have as minimum a bachelor's degree in some scientific field and a fundamental understanding of radioactivity, its measurements and its effect on man. The training requirements outlined in this section are thus devoted to familiarizing such personnel with the character of the problems to be investigated, the methods of analysis used, the types of equipment used to simulate and measure contaminated fields and the safety precautions required.

Because of the nature of the subjects that must be covered, the training course must be divided between class work, laboratory work and on-the-job training. The major subjects that must be covered in the classroom are the nature of the fallout problem and its interrelation with the computational techniques developed; the understanding and use of a shielding theory and its specific application to the fallout program as outlined in such texts as "The Design and Review of Structures for Protection from Fallout Gamma Radiation," "Structure Shielding Against Fallout Radiation from Nuclear Weapons" (NBS Monograph 42), "Radiation Shielding" by Price, Horton and Spinney, and Glasstone's "Principles of Nuclear Reactor Engineering," "Radiation and its Effect on Mankind," and the more general aspects of radiation safety.

The laboratory phase of the training should consist of instruction and practice in the use and minor maintenance of radiation detection equipment including equipment used for personal protection, general survey work and the experimentation, the use and maintenance of circulating source equipment including emergency procedures used to recover from unforeseen incidents and the methods and techniques of instrument calibration. This laboratory training phase should be followed by intensive on-the-job training in the use of the experimental equipment for a period

of not less than six months. At the conclusion of the training program a comprehensive written examination designed to test each applicant as to his ability to think operations through with particular regard to unforeseen emergency conditions and his general knowledge of radiation safety should be administered before the applicant's name is submitted for inclusion on the AEC license as a responsible operator.

A brief proposed course outline to accomplish these purposes is presented below together with a rough estimate of the time required for each portion of the outline.

	Lecture	Study
Classroom		
The Nature of the Fallout Problem	2	6
The Computational Techniques used in Fallout Shielding Analysis	8	40
Radiation and Its Effect on Mankind	1	4
Radiation Safety	2	10
	Laboratory	**Study** (Hours)
Laboratory		
The Use and Minor Maintenance of Radiation Equipment	8	8
The Use of the Circulating Source System	4	8
Radiation Safety with the Circulating Source System	4	16
Methods of Calibration	32	8
On-The-Job Training	**Job Time**	
Radiation Safety	8 hours	
Operational Techniques	8 hours	
Supervised on-the-job Experience	Minimum 6 months, maximum depending on the individual	
General Examination		
Theory	1 hour	
Operational Techniques	1 hour	
Radiation Safety and Emergency Procedures	2 hours minimum	

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